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Electric Bells, How to Make and Fit Them. With 162 Engravings and Diagrams.

Contents.—The Electric Current and the Laws that Govern it. Current Conductors used in Electric Bell Work. Wiring for Electric Bells. Elaborated Systems of Wiring; Burglar Alarms. Batteries for Electric Bells. The Construction of Electric Bells, Pushes, and Switches. Indicators for Electric Bell Systems. Index.

Bamboo Work. With 177 Engravings and Diagrams.

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ELECTRIC BELLS

HOW TO MAKE AND FIT THEM

INCLUDING

BATTERIES, INDICATORS PUSHES, AND SWITCHES

WITH NUMEROUS ENGRAVINGS AND DIAGRAMS

EDITED BY

PAUL N. HASLUCK

EDITOR OF "WORK" AND "BUILDING WORLD"
AUTHOR OF "HANDYBOOKS FOR HANDICRAFTS," ETC. ETC.

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PREFACE

This Handbook contains, in a form convenient for everyday use, a comprehensive digest of the knowledge of the Construction and Fitting of Electric Bells, Batteries, Indicators, Pushes, and Switches, scattered over ten thousand columns of Work—one of the weekly journals it is my fortune to edit—and supplies concise information on the general principles of the subject on which it treats.

In preparing for publication in book form the mass of relevant matter contained in the volumes of Work, much had to be arranged anew, altered, and largely re-written. From these causes the contributions of many are so blended that the writings of individuals cannot be distinguished for acknowledgment.

Readers who may desire additional information respecting special details of the matters dealt with in this Handbook, or instruction on kindred subjects, should address a question to Work, so that it may be answered in the columns of that journal.

P. N. HASLUCK.

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ELECTRIC BELLS

CHAPTER I.

THE ELECTRIC CURRENT AND LAWS THAT GOVERN IT.

IT is advisable before dealing with practical electric-bell work to know something of the laws of the electric current and to gain some familiarity with the technical terms and their meaning. In commencing either the study or the practice of electrical engineering a difficulty always arises in understanding the system of units employed. This is largely due to the fact that the real nature of electrical phonomena is not yet thoroughly understood, and also to the fact that electricity is not something which actually exists and can be measured directly as by the foot-rule, but is rather a condition of matter. While the ultimate cause of certain effects may be obscure, the effects themselves may be measured readily if the proper units be chosen. For practical purposes there need be no more difficulty in measuring electrical effects by means of electrical units than there is in measuring the effects of gravity, the real nature of electricity being about as well understood as that of gravitation.

For dealing with electrical phenomena the ordinary units of measurement do not apply directly, and therefore a set of suitable units have been derived from the fundamental units of time, length, and mass. To explain the application of these units to electrical subjects, it is simplest to imagine electricity to be a current passing through the wires, or whatever may form the conductor, and the resemblance of a current of water when

passing through a pipe is used for the purpose of comparison. It must be remembered, however, that, apart from whatever doubt may exist as to the true nature of electricity, it is now agreed that nothing in the nature of an ordinary current actually passes through the conductor.

Perhaps it is best to begin by saying that, having no real knowledge of the nature of electricity, for the purpose of explaining electrical work it is convenient to suppose that electricity is matter which can flow from one place to another; in fact, it may be thought to have many of the properties of water. Thus,

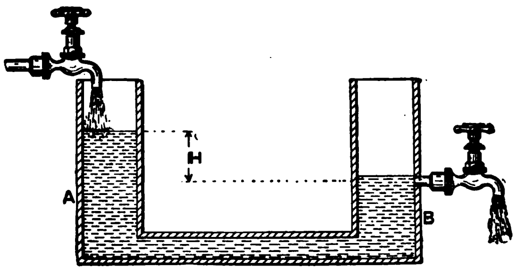


Fig. 1.—Flow of Water analogous to the Passage of the Electric Current.

if there are two connected cisterns, A and B (Fig. 1), containing water, the difference of levels H being maintained by suitably adjusting the in and out flow taps, there will be a continuous flow of water through the connecting pipe equal, say, to three pints per minute past any section. The flowing water may be made to perform work by driving a water motor, and the total amount of work done may be calculated in foot-pounds by multiplying the weight of water that has passed through the pipe by the height H through which it has fallen.

Applying the hydraulic illustration, when a current of water passes through a pipe it usually does so because of a difference of level between the two ends of the

stream. Similarly an electric current is due to a difference in the capacity for performing work, called potentials, between two points in the circuit. Two electrified bodies will have their potentials differing from unelectrified bodies, whilst between the two bodies there may be no potential difference. It is therefore necessary to have a standard of comparison to which the potentials of various bodies may be referred. The earth is assumed to be electrically at zero or no potential, and bodies which are at a potential higher than that of the earth as a whole are said to be electrified positively, while electrified bodies at a lower potential relative to the earth are said to be negative.

Two bodies of water at equal height above sea level joined by a pipe would not flow either way, because there is no "fall" or difference of level; similarly, if two bodies electrified at equal potentials above or below that of the earth be joined, there will be no passage of electrical current. From this it will be understood that it is the difference of potentials which causes a flow of electric current between two bodies, and even if one of the bodies is not electrified or at zero potential, a current may be caused by the other body having a difference of potential. Generally speaking, another name for difference of potential is electro-motive force, although some attempt has been made to distinguish between the two terms.

Now the total amount of work done and the rate of doing work may be distinguished between. The latter is often denoted by the power or activity of the agent, and Watt estimated that the rate of doing work of a horse was equal to 33,000 ft.-lb. per minute. Hence, if a horse worked for ten minutes it would do 330,000 ft.-lb. as the total amount of work. It is, however, often convenient to express the total work in horse-power hours. Electrical energy may be considered in two parts or components—volts and ampères—and when they are multiplied together watts are produced. Electrical energy expenditure at the rate of 1,000

watts per hour is called a Board of Trade unit; so that a current of 1,000 ampères at an electro-motive force of 1 volt supplied for one hour is a Board of Trade unit. The "ampère" is the unit of current strength, the "volt" the unit of pressure. A current of high voltage and low ampèrage, such as that produced by connecting together in series a great number of small battery cells, can be compared to a very high water tank with a very small hole in the bottom, which squirts out a very small quantity of water with great pressure. A current of low voltage and high ampèrage, such as that produced by connecting together in parallel a great number of large cells, can be compared to a huge, shallow water tank with a large hole in the bottom, giving a large quantity of water at a very low pressure.

To make all this directly applicable to the measurement of electrical work and power, it is only necessary to substitute: For head of water in feet, or difference of water pressure, write difference of electrical pressure; for rate or strength of water-flow in pounds per minute, write strength of electrical current; for quantity of water in pounds, write quantity of electricity. Then the electrical work will be equal to difference of electrical pressure multiplied by the quantity of electricity. The volt is the unit by which differences of electric pressure or potential are measured, and the word voltage is also applied in the same sense. If the current of electricity is to be kept constant the difference of potential, electro-motive force, or voltage must also be kept constant, for, on joining two bodies at a difference of potentials, electricity will pass from the body at the higher potential to that at the lower until the two are at the same absolute potential. Therefore to maintain a current means must be taken to keep up a difference of potential. As electricity is not matter, objection has been made to the term electro-motive force, because force is that which moves, or tends to move, matter. At the same time currents which, in the ordinary sense of the word, do not exist, are still spoken of

The volt, which is the unit by which differences of electrical potential are measured, may be defined as that electro-motive force which, on a circuit of unit resistance, produces unit currrent. Here units of current and resistance are involved.

Another method of defining potential difference is by the work which would be done under certain circumstances either electro-statically—that is, with electrical charges—or electro-magnetically—that is, by an electric current. Thus, electro-statically, the volt is that difference of potential which exists between two points when one unit of work (one erg) is spent by the unit quantity of electricity in moving from one to the other against electrical repulsion. Similarly, electro-magnetically, unit electro-motive force is the electro-motive force between two points on a circuit, when unit current, flowing for unit time, does unit work between these points.

From what has been stated it may be seen that electrical powei = difference of electrical pressure × strength of electrical current. Ergs = number of units of electrical pressure × number of units of electricity, and, ergs per second = number of units of electrical pressure × number of units representing current strength.

For practical purposes it has been determined to have units larger than the erg and erg per second, and to change the units of electrical pressure, electrical quantity, and current strength as expressed by the above equations, so that a unit 10,000,000 times larger than the erg is obtained. This practical unit is called the joule, taking its name from J. P. Joule, who determined the relation between work and heat. The rate of doing work expressed by a joule per second is called the watt, after Sir James Watt, who, as before said, established the English horse-power unit of activity.

The names of the electrical units are as follows :— Pressure—the volt; quantity—the coulomb; current—the ampère: these terms are derived from the names

of the eminent electricians, Volta, Coulomb, and Ampère.

New equations may now be written out as below :—

Joules = coulombs × volts

Watts = ampères × volts

So that these equations may be thoroughly understood, it is necessary to suppose that, provided with suitable instruments, electrical measurements may be made. Two instruments only will be really necessary—namely, an ammeter for indicating ampères, and a voltmeter for indicating volts.

The following table shows the electro-motive force in "legal" volts, except in the case of the Latimer-

Name of Cell.	*Approximate E.M.F. Volts.*	*Remarks.*
Daniell	1·07–1·14	Gives steady current.
Grove	1·9–1·95	Small internal resistance ; large current.
Bunsen	1·9	—
Potassium bichromate (Poggendorff) ...	2	Large current.
De la Rue	1·05	—
Leclanché	1·5	Intermittent current polarises quickly.
Gassner	1·3	Dry cells.
Hellesen	1·45	do.
Burnley or E.C.C. ...	1·45	do.
Obach	1·5	do.
Edison-Lelande ...	·75	Low resistance.
Latimer-Clark ...	1·434	Standard cell.

Clark or Standard cell, of several of the better-known primary cells. This unit depended on the "legal" ohm, but by the Order in Council, August 23, 1894, the "international" volt, depending on the "international" ohm, is now used as the standard. This order defined the volt as "the electrical pressure that if steadily applied to a conductor whose resistance is 1 ohm will

produce a current of 1 ampère," being "represented by ·6974 ($\frac{1000}{1434}$) of the electrical pressure at a temperature of 15° C. between the poles of a voltaic cell known as Clark's cell." A specification of this cell was given, containing directions for the preparation of the materials and for setting up the cell.

Another practical unit of difference of potential, now out of date, was the B.A. (British Association) volt. For the purpose of comparison it may be noted that 1 international volt equals, roughly, 1·0023 legal volts or 1·01358 B.A. volts. Therefore 1 legal volt equals $\frac{1}{1 \cdot 0023} = \cdot 997$ international volts, and 1 B.A. volt equals $\frac{1}{1 \cdot 01358} = \cdot 986$ international volts. The B.A. volt is seldom or never used, but both the legal and the international units are used, and some confusion still exists between them.

The idea of a current of electricity acting through a conductor being like water passing through a pipe has already been conceived, and it follows that opposing the current of water there will be frictional resistances. Similar in some respects to this frictional resistance is the resistance that a circuit offers to an electric current, though the laws that govern the two sets of resistances are in many cases quite different. For instance, a passage of water through a solid is impossible; and while frictional losses which occur in water pipes may be largely increased by bends, no such loss need occur if the conductor of the electric circuit be bent.

Most electrical engineers, however, prefer to regard resistance simply as a property of matter. This is the way in which it is dealt with in the Order in Council before mentioned, where the practical unit of resistance or ohm is defined as being "represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14·4521 grammes in mass of a constant cross sectional area and of a length of 106·3 centimetres."

This practical international ohm is 10^9 (1,000,000,000) times the absolute unit on the electro-magnetic system. Its relation to the legal ohm and to the B.A. ohm is the same as that given on the previous page for the various standards of voltage.

A favourite method with physicists and teachers of stating Ohm's law is that "the ratio of the difference of potential between two points on an electrical circuit to the current is constant for a given conductor at constant temperature." The law may be stated in a way more helpful for practical purposes in the following terms:—The current in ampères in a given circuit equals the difference of potential in volts between any two given points, divided by the total resistance of the circuit in ohms between those points. Any difficulty in understanding the units involved has been cleared away by the explanations already given. A mathematical way of stating Ohm's law is—

$$\text{Current (in ampères)} = \frac{\text{electro-motive-force (in volts)}}{\text{total resistance (in ohms)}}.$$

The resistance of an electrical conductor or circuit depends directly on its length. For instance, in two conductors exactly alike, except that one is four times the length of the other, the longer one will have a resistance four times as great as the shorter one. The resistance will also vary inversely as the cross-section, so that a wire with twice the cross-sectional area of another will have one-half the resistance, so the resistances of round conductors vary inversely as the square of their diameters. Therefore, in two conductors, alike in every respect, except that the diameter of one is five times that of the other, the larger one will have a resistance $\frac{1}{5 \times 5} = \frac{1}{25}$ the resistance of the conductor with the smaller diameter. Conductors other than round, of course, follow the same law, but are not used to such a large extent as are round wires.

The resistance of a conductor will also vary with the *specific resistance* of the material employed. A table

of specific resistances for many materials both in ohms

Material.	*Resistance per Cubic Inch.*		*Resistance per Cubic Centimetre.*	
	Ohms.	*Micr-ohms.*	*Ohms.*	*Micr-ohms.*
Aluminium ...	0·00000114	1·14	0·0000029	2·9
Brass from ...	0·0000021	2·1	0·0000058	5·8
to	0·0000028	2·8	0·0000072	7·2
Copper (annealed) from	0·00000061	0·61	0·00000155	1·55
to	0·00000063	0·63	0·00000161	1·61
Copper (hard drawn) from	0·00000062	0·62	0·00000159	1·59
to	0·00000064	0·64	0·00000164	1·64
Carbon (arc lamp) from	0·0017	1700·0	0·0044	4400·0
to	0·0034	3400·0	0·0086	8600·0
Gold (annealed)	0·0000008	0·8	0·00000205	2·05
Gold (hard drawn) ...	0·00000082	0·82	0·00000209	2·09
German silver from ...	0·0000074	7·4	0·000019	19·0
to	0·0000118	11·8	0·000030	30·0
Iron (annealed) from ...	0·0000038	3·8	0·0000096	9·6
to	0·00000405	4·05	0·0000104	10·4
Lead	0·0000077	7·7	0·0000196	19·6
Manganin ...	0·000018	18·0	0·000044	44·0
Mercury ...	0·0000366	36·6	0·000095	95·0
Nickel ...	0·0000049	4·9	0·0000124	12·4
Phosphor-bronze	0·00000307	3·07	0·0000078	7·8
Platinoid ...	0·000014	14·0	0·000034	34·0
Platinum ...	0·00000355	3·55	0·000009	9·0
Platinum silver from ...	0·0000095	9·5	0·000024	24·0
to	0·00000958	9·58	0·0000243	24·3
Silver (annealed)	0·00000058	0·58	0·00000147	1·47
(hard drawn)	0·00000062	0·62	0·00000158	1·58
Tin	0·00000519	5·19	0·0000132	13·2
Zinc	0·00000221	2·21	0·0000059	5·9

and microhms is given above. A microhm is a unit employed for measuring very small resistances such as

B

are now being considered, and it equals one-millionth part of an ohm. Similarly, for measuring high resistance, such as the insulation of an electric lighting cable, the megohm is used, one megohm being equal to 1,000,000 ohms.

Increase of temperature is the cause of the increased resistance of a conductor; there are one or two exceptions. Some brands of manganin, an alloy of

Material.	*Percentage Increase of Resistance in Ohms.*	
	Per degree C.	*Per degree Fah.*
Aluminium	0·39	0·217
Copper	0·388	0·215
Carbon *	0·052	0·029
Gold	0·365	0·203
German silver	0·044	0·024
Iron	0·453	0·251
Lead	0·387	0·215
Mercury	0 072	0·040
Platinum	0·247	0·137
Platinoid	0·021	0·010
Platinum silver	0·031	0·017
Silver	0·377	0·209
Tin	0·365	0·203
Zinc	0·365	0·203

copper, manganese, and nickel in proportions of about 85, 12, and 3 per cent., do not vary in resistance to any appreciable extent with increase of temperature; while, as regards better-known materials, the resistance of carbon actually decreases with increase of temperature.

A table of percentage increase of resistance per degree Centigrade and per degree Fahrenheit is given above; but it is not certain that the increase of resistance is in direct proportion to the increase of temperature.

* The variation for carbon is a decrease with increase of temperature.

For most practical purposes, however, it is sufficiently correct to assume this.

A table of resistances for the more usual sizes of copper wires of 100 per cent. conductivity at a temperature of 65° F. will be found on p. 25. The following well-known approximation may prove useful as a guide to judging resistance. A wire of pure copper 10 mills. ($\frac{1}{100}$ in.) diameter by 10 in. long, has a resistance of 1 ohm at a temperature of 15·5° C., or 60° F. If the wire were of 99½ per cent. conductivity, the difference between its resistance and the standard practical ohm would be negligible.

The unit of current strength, that is the ampère, may now receive further attention. Referring to the hydraulic illustration, it may be said that the current strength corresponds to the rate at which the water flows in a pipe. Unit current may be defined in terms of the other electrical units, as being that current which is produced by unit difference of potential acting on unit resistance. This is, of course, only the statement of a special case of Ohm's law. There are other terms of definition of an electric current, and the two principal of these for this purpose are its magnetic and its chemical properties.

The electro-magnetic absolute unit of current may therefore be defined as that current which, flowing through an arc of unit length, with a radius of unity, acts with unit force on a magnetic pole of unit strength placed at the centre. As will be gathered from the contents of previous pages, the fundamental unit of length is the centimetre (·3937 in.) which is also the radius referred to, while unit force is the dyne. Without going deeply into the matter, a magnet pole of unit strength is that which at unit distance (1 centimetre) from a similar pole repels it with unit force (1 dyne).

The current just defined is the electro-magnetic absolute unit; unlike the absolute units of potential difference and resistance, it is too large for ordinary purposes, and the practical ampère is one-tenth of the absolute unit. This follows from the definition of

unit current given above. Since 1 practical volt equals 1,000,000,000 absolute electro-magnetic volts, and 1 practical ohm equals 1,000,000,000 absolute electro-magnetic ohms, it will be evident that 1 practical ampère must equal $\frac{100,000,000 \text{ absolute volts}}{1,000,000,000 \text{ absolute ampères}}$ = one-tenth absolute ampère.

The ampère is defined legally by the chemical properties of the electric current, and the Order in Council, 1894, states that the ampère "is represented by the unvarying electric current which when passed through a solution of nitrate of silver in water," in accordance with a given specification, "deposits silver at the rate of 0·001118 of a gramme per second." The specification referred to above gives particulars of the apparatus to be employed (the silver voltameter), and also explains how to make the measurement.

The electrical unit of quantity, sometimes confused with that of current, is the coulomb. This is the ampère multiplied by the second, and as the practical ampère is one-tenth the absolute unit, the practical coulomb is one-tenth the absolute coulomb. The coulomb is, however, seldom used, and the "ampère-hour" (current in ampères multiplied by the time in hours) is employed instead.

The unit of capacity is the farad. This may be defined as the capacity which requires a quantity of one unit to raise its potential 1 volt. Since among practical units the coulomb and the practical volt are employed, it can be shown, by similar reasoning to that adopted in the case of the practical ampère, that the practical farad is $\frac{1}{1,000,000,000}$ of one absolute unit of capacity. Notwithstanding this apparently small value, the farad is far too large a unit for practical requirements, and in its place the microfarad and fractions of the microfarad are employed. The microfarad is equal to $\frac{1}{1,000,000}$ of 1 farad.

Here it may be explained that in electrical technical terms the prefix meg or mega means 1,000,000. Thus 1 megohm = 1,000,000 ohms, and 1 megavolt = 1,000,000 volts. Micro, as microfarad, stands for $\frac{1}{1,000,000}$; microhm or $\frac{1}{1,000,000}$ of 1 ohm, and micro-volt or $\frac{1}{1,000,000}$ of 1 volt. Milli stands for $\frac{1}{1,000}$, as milli-ampère already mentioned.

Henry is the name now most used for the practical unit of self-induction, and in so doing the practice is being followed of naming the electrical units after distinguished electricians, as in the cases of the volt, ampère, ohm, coulomb, etc., already mentioned.

The joule has been proposed and adopted as the unit to measure the work done electrically (see p. 13). It may be defined as the work done when 1 coulomb passes in a circuit, the terminals of which are at a difference of potential of 1 volt. By referring to the practical values of the units of quantity and electro-motive force, it will be seen that the practical unit must be 10,000,000 times the absolute unit. The joule is but seldom used in practice; roughly it is equal to 0·737 ft.-lb. of work.

The watt is the unit of power or activity (rate of doing work). It is equal to 1 joule per second. On any circuit the power is equal to the steady current in ampères multiplied by the steady electro-motive force on the circuit in volts. Since 1 watt equals 1 joule per second, or 0·737 ft.-lb. of work per second, it is also equivalent to $60 \times {}\cdot 737 = 44\cdot 22$ ft.-lb. of work per minute, so that 1 watt equals $\frac{44\cdot 22}{33,000}$ or $\frac{1}{746}$ horse-power (approximately). In other words, a power of 746 watts equals 1 horse-power. Kilowatt simply means 1,000 watts; it is the measure of electrical power or rate of doing work usually applied to large electrical outputs, and can be determined by multiplying the electro-motive force in volts by the current in ampères and dividing by 1,000. The kilowatt is the Board of Trade

unit of energy, that is, it is the measure by which electrical energy is sold for lighting, power, heating, etc. It is the work done on a circuit when the power in watts multiplied by the time in hours equals 1,000; in short, one Board of Trade unit equals 1,000 watt-hours. Taking the horse-power-hour as the mechanical unit of energy, the Board of Trade unit—or unit, as it is often called for shortness—equals $\frac{1,000}{746} = 1{\cdot}34$ horse-power-hours. To find the number of units used in a given time on a given circuit, proceed as explained above—multiply the average current in ampères by the (presumably) steady electro-motive force in volts and by the time in hours, and divide the product by 1,000.

CHAPTER II.

CURRENT CONDUCTORS USED IN ELECTRIC BELL-WORK.

THE electric current employed in ringing bells, lighting lamps, and working motors, always moves in a circuit. It passes, from its point of generation, through a series of conductors, does its work, and returns to its starting place. Thus does the electric current differ from other forces. Steam does useful work, and then passes onward into the air; water passes from a higher to a lower level, does work in its course, but does not go back to the point from which it started; gas passes through

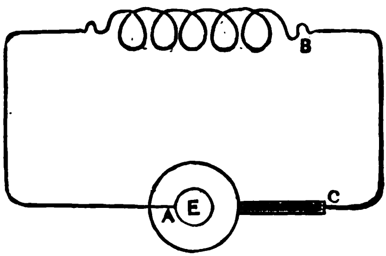


Fig. 2.—A Simple Electrical Circuit.

pipes, does its work, and then is exhausted. It is not necessary to provide a return path for any of these sources of power; but there must be a return path provided for an electric current, and this path must be as good as that which leads out from the electric generator, which may be a battery or a machine.

A simple electrical circuit is illustrated by Fig. 2, in which E is the cell; A shows the point of departure of the current, B the coils of wire on the bells and indicator, and C the return wire. In the same way as suitable pipes must be provided to carry steam, water or gas, so must suitable material be employed for the

conveyance of the electric current. Metals are the most serviceable materials, and of these silver is the best, copper coming next; this may be seen on reference to the table on p. 17. A portion of the pressure of steam, water, and gas is absorbed by friction on the sides of the pipes, and, as has been said, electrical energy is absorbed in being transmitted through its circuit. All metals have not an equal conductive capacity for the electric current. Silver is regarded as the unit of resistance, and it may be seen from the table previously referred to that copper offers only a little more resistance than silver, whilst zinc has about 3¾ times, brass 5 times, and iron 6½ times more resistance, and consequently a comparatively less conductive capacity. Therefore, if an iron wire were to be used instead of a copper wire, to carry an equal current, the sectional area of the iron wire must be nearly 6½ times that of the displaced copper wire. Well annealed and soft copper offers less resistance than when hard-drawn, pressed, or hammered. All wires should, therefore, be soft; that is to say, well annealed. It has been pointed out that resistance increases with increased length and decreased diameter of a conducting wire. The table on p. 25 shows how copper wires increase in resistance with decrease in size, and with increase in length. The upper figures in the left-hand column give standard wire gauge sizes of wires in general use for electric-bell lines, the lower figures give sizes of wires employed in winding the bobbins of bells and indicators. As part of the current may pass through these finer wires, as well as through the larger ones, they must also be taken into account when reckoning the resistance of the whole circuit.

To repeat in substance what has already been given in Chapter I., the current flowing in a circuit of conductors equals the pressure of that current, divided by the resistance of all the conductors. This is frequently shown in text books on electricity by the simple formula $C = \frac{E}{R}$, which means: C, the current, equals E, the electro-

S.W.G.	Size.		Weight in lbs. per 1,000 Yards.	Yards to the lb.			Resistance in Ohms per lb. Bare Wire.	Resistance in Ohms per 1,000 yds.
	Inch.	**Mm.*		*Bare.*	*Silk-covered.*	*Cotton-covered.*		
8	·160	4·064	232·320	4·3	4·25	4·25	·00517	1·2022
10	·128	3·251	148·686	6.7	6·56	6·36	·01263	1·8785
12	·104	2·642	98·154	10·2	10·12	9·82	·02899	2·8455
14	·080	2·032	58·080	17·2	16·90	16·70	·08279	4·8090
16	·064	1·626	37·167	26·9	26·30	24·80	·20217	7·5141
18	·048	1·219	20·9088	47·9	47·00	45·00	·63880	13·3584
19	·040	1·016	14·5200	72·5	71·00	69·00	1·3248	19·2360
20	·036	·914	11·7612	85·0	83·00	80·00	2·0192	23·7480
21	·032	·813	9·2928	122·0	120·00	117·00	3·2345	30·0570
22	·028	·711	7·1148	140·5	138·40	129·40	5·5178	39·2580
23	·024	·610	5·2272	184·0	181·50	173·00	10·2220	53·4330
24	·022	·559	4·3923	227·7	224·30	215·30	14·4780	63·5910
25	·020	·508	3·6300	283·5	279·30	266·80	21·1970	76·9440
26	·018	·457	2·9403	340·2	336·70	316·70	32·3070	94·9920
27	·0164	·417	2·4408	420·3	412·40	392·10	46·8840	114·435
28	·0148	·376	1·9878	503·0	490·80	467·20	70·6870	140·511
30	·0124	·315	1·3953	716·8	694·10	670·10	143·4500	200·166
32	·0108	·274	1·0585	946·1	914·20	870·20	219·2800	263·871
34	·0092	·2337	·7681	1302·1	1239·3	1163	473·4200	363·630
36	·0076	·1930	·5241	1908·4	1791·4	1613	1016·600	532·860
38	·0060	·1524	·3267	3058·1	2806·1	—	2616·900	854·940
40	·0048	·1219	·2090	4785	4365	—	6388·900	1335·84
42	·0040	·1016	·1452	6897	5743	—	13246	1923·60
44	·0032	·0813	·0929	10753	8297	—	32345	3005·7
46	·0024	·0610	·0522	19231	13712	—	102220	5343·3
47	·0020	·0508	·0363	27586	20700	—	211970	7694·4

motive force, divided by R, the resistance. If, therefore, the electro-motive force of the battery measures 4·8 volts, and the total resistance of battery, bell, indicator, lines and pushes measures 8·4 ohms, the current will be shown by this formula: $\frac{4 \cdot 8}{8 \cdot 4} = \cdot 57$ ampère, or a little more than ½ ampère. If, therefore, the bell will need ½ ampère of current to ring it properly, the resistance of the whole circuit must be kept below 9·6 ohms. The internal resistance of bell-ringing batteries, even when the batteries are new, is high, and resistance increases with age. The wires and connections of the bell and indicator have also a high resistance, which cannot be always economically lessened, and which increases with use. These may be regarded as the natural or

* Millimetres.

necessary working resistances of the circuit, which cannot be made less by the bell-fitter. The lines, however, are under his control, and he can lessen the resistance by a proper choice of wires, the adoption of a good system, and careful workmanship. If he adds to the natural resistance, by bad joints, long thin lines, careless laying of the wires, and loose connections, the bell will not ring well, and its tone will gradually diminish because of added resistance incidental to corrosion. Even one bad joint will increase the resistance very much as time passes, because atmospheric influences will oxidise the joint, and metal oxides (rust, verdigris, green corrosion) offer a higher resistance than the metals themselves.

Painted wood, damp wood, damp walls, water, earth, coal, coke, and many similar things in and about a house, will conduct the electric current, although in a degree inferior to metals. If the bare line wires are connected by any of these substances, a leakage of the current will take place from line to line; and this will divert part of the energy from its useful path. This leakage may soon exhaust the battery.

Though there are many substances which are bad conductors, a non-conductor of electricity does not exist. When a good conductor is enveloped in a bad conductor, it is said to be insulated, because the conductor is surrounded by substances which cut it off from electrical contact with other conductors. Conductors of the electric current must be insulated from each other throughout the circuit. Among bad conductors employed as insulators in electric-bell work are dry wood of various kinds, ebonite, vulcanite, vulcanised fibre, woodite, guttapercha, indiarubber, cotton, wool, silk, glass, china, porcelain, wax, resin, shellac, and paraffin wax; dry air, fats, and oils are also bad conductors, but, as may be supposed, are rarely used as bell-line insulators.

Wires that lead from the battery to the electric bell and back to the battery are named line-wires. These main conducting wires are named "leads."

Electric-light wires may be used as conductors for electric bells, but the class of wires employed for electric-bell lines is not suitable to electric lighting work, and it is usually best to employ a separate line and system of wiring for the two services. Line-wires for electric-bell work are made of H.C. (high conductivity) copper wire, insulated with cotton and paraffin, to which india-rubber is added sometimes. The wire must be well annealed to get its highest value as a conductor, and to facilitate the work of laying it. The best quality line wires are coated with cotton saturated with molten paraffin, in addition to coats of indiarubber, gutta-percha, or insulating varnish. Wires for bobbins are coated with silk or cotton, and the metal fittings are mounted on dry polished wood, ebonite, china, or similar insulating substances. Line wires thus perfectly coated, and fittings mounted on good insulators may be used, but the insulation of the circuit may be entirely destroyed by a screw driven through an insulator, or staples driven so as to cut through the cotton covering of the wires. One such bridge will unite the conductor with other conductors, and destroy the insulation. A bell-fitter must therefore see that the insulation is good throughout the circuit.

Electrical energy is caused by chemical or mechanical changes in the substances forming the generator. Its amount is proportioned to the chemical or mechanical energy employed. Therefore, when these are feeble, the electric current will also be feeble. When a battery is partly exhausted, its contents offer a higher resistance than that of new materials—hence more force must be employed to push the current through this added resistance. The condition of the circuit then resembles that of a line of gas or water pipes choked by corrosion.

The sizes of wire in general use for electric-bell work are Nos. 20 and 22 B.W.G. (Birmingham Wire Gauge). Occasionally, in large installations, No. 18 is employed; No. 22 may be used for very short lines, but for longer lines No. 20 will be found most economical; and it is

the gauge in general use. No. 20, being of greater sectional area, offers less resistance than a wire of equal length made of No. 22 wire. The smaller wire is also more liable to break whilst being drawn through tubes, and holes under flooring. Cheap No. 22 H.C. copper wire D.C.C. and paraffined has its core cased in strands of white cotton, laid longitudinally, around which are wrapped several strands of coloured cotton, thus covering it with a double cotton cover, represented by the letters D.C.C. The cotton-covered wire is then run through a vessel containing molten paraffin wax, which sinks into the covering, this being afterwards polished by machinery. Nos. 20 and 18 are also thus cheaply insulated when required. Such an insulation may be employed in very dry situations, such as under the floors of upper rooms; but as paraffin wax does not resist damp, these cheap wires should not be laid in tubes, nor in any situation liable to become damp. It not infrequently happens that wires thus cheaply insulated corrode with damp under the cotton, and literally drop to pieces in the places where they are hid.

A higher class of insulation is described as "I.R.D.C.C. and paraffined." The copper wire is first run through a bath of molten tin, to protect the copper from the action of any sulphur held in the rubber coating; the wire is then enveloped in indiarubber, cased in several strands of white cotton laid longitudinally, then wrapped in several strands of coloured cotton wound spirally over all; the whole is then run through molten paraffin wax, and polished as before described. This insulation is in general use for first-class work. A good insulation for electric-bell wires is a varnish variously described as Fowler-Waring compound, patent compound, compound varnish, and Okonite compound. Cotton or tape saturated with this compound is wound spirally around the wire, and allowed to dry. It is then braided with coloured cotton (Fig. 3), saturated with paraffin wax, and polished. Line wires thus treated are superior to those with rubber and cotton insulation,

as the compound adheres so closely to the wire as to leave no part loosely covered; the braiding also provides a compact outer coating which is not liable to strip from the wire whilst it is being drawn through tubes and holes. The coating is also very durable, even when employed in damp situations.

The outer coating of electric-bell line wires is of coloured cotton. When ordering this wire it is advisable to specify delivery in assorted colours. The colours in general use are red, blue, green, and yellow. These are termed plain colours, and when only one colour prevails on a coil of wire covered spirally with cotton, the cotton is said to be "lapped." Some vendors affect two colours on one wire, one being a ground colour of white, yellow,

Fig. 3.—Wire with Braided Insulation.

buff, or light brown, the other red, blue, green, or black wound over spirally with spacing between the laps, so as to give it a spiral appearance. Wire thus covered is said to be "whipped." Braided wires are usually covered in two colours. By employing assorted colours on a large job, one line may be distinguished from another, and branch lines from main lines. When it is necessary to run exposed lines along a skirting, chair-rail, or dado, a twin-line wire with an outer coating to match the paint or decoration should be chosen. These twin wires are simply two insulated wires running side by side under one outer coating. Their inner coatings should be of different colours, to distinguish the two wires. In the commoner class of twin wires the insulation is simply double-cotton-covered and paraffined; but as this is not reliable in lines run so close to each other, there should be an additional insulation of rubber or special compound. The best wires are coated with good rubber, then double-coated with cotton and paraffined. The two wires are then enveloped in cotton, and the covering is soaked with

paraffin. The second grade has only one wire coated with rubber, and the other double-cotton covered, all the other conditions being fulfilled. Current leakages are often traced to cheap twin-line wires. Use only the best of twin wires for laying along the wainscot of a room, as the money saved by using cheap wire generally has to be spent afterwards in repairs and renewals. Twin wires are described by the signs 2/18, 2/20, 2/22, etc., meaning two lines of No. 18, etc.

When extensions of an electric-bell system are desired for temporary use, such as a line to ring a bell

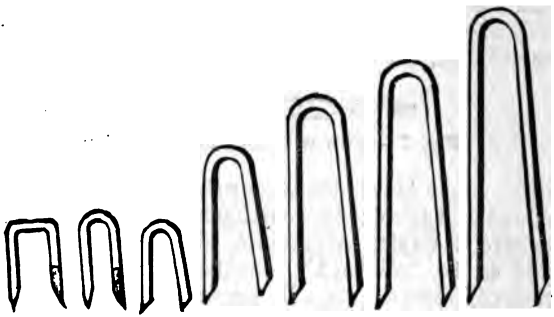


Fig. 4.—Staples for Securing Wires.

or dinner gong on a table, it is advisable to use flexible conducting cord, run under a carpet. These flexible conductors are also necessary to extend the system in bedrooms to the sides of beds, as single copper wires would be stiff, and liable to become broken from frequent bending. A flexible conductor is made by massing together six, nine, or twelve fine soft copper wires under one coating. The wires in general use for this purpose are Nos. 36, 38, and 40, and the conductors are distinguished as 6/36, 9/38, and 12/40, etc., the gauge of wire being placed in the last place, and the number of strands first. These cords are sold under the name of pear pressel cords, thin, medium, or thick. The insulation is usually of longitudinal strands of cotton, overwound

spirally with green silk. In the thin and commoner kinds the two covered conductors are simply twisted together to form the cord; in the thick cord a third strand of silk-covered cotton is introduced to form a threefold cord. In a better class the two conductors are enveloped in a braided coat of silk. In a still better class a rubber insulation is added. These cords are also made to order in a variety of fancy braidings in cotton, glazed cotton, worsted, and silk.

Line wires laid along walls and woodwork are secured thereto by iron or steel wire staples of many shapes and kinds (Fig. 4). An insulating saddle staple of metal and vulcanised fibre (Fig. 5) minimises the

Fig. 5.—Insulating Saddle Staple.

danger of injuring the wires by driving. Front and side views of the staple are given in the illustration.

Exposed wires are liable to be damaged or tampered with, and as they are considered unsightly, efforts are usually made to conceal them as much as possible. For example, commencing with a push, in an upper room, fixed close by the fireplace, the wires are hid under the paper and laid along by the mantel down to the floor, under this if possible, and out of the room under the doorway. If the bell is to be rung from a pear pressel by the side of a bed, the flexible cord terminates in a rose near the ceiling, and the line wires are laid under the paper at the top until the doorway is reached, then down by one of the doorposts and out behind it through the wall. Good wall-paper may be stripped back from the top and repasted over the wires

after they have been fixed; it may also be slit with a sharp knife, the edges laid back, a groove scraped in the plaster for the wire, and the slit paper pasted over the wire. This cannot be done with common paper, and in such cases, as also when the wires cannot be laid under the floor, they may be run in a groove of the chair rail, or skirting, or along on the edges of these. Line wires may be laid around corners without interfering with their current carrying qualities, provided they are not kinked, stretched, or injured by having their covering stripped.

Two or more wires should never be secured under one staple, nor the staples on neighbouring lines be allowed to touch each other; but wires may be laid side by side, and may cross each other if the insulating covering of both is uninjured. Two wires secured under one staple may allow leakage across the bridge; a similar leakage may be caused by two bare wires being laid in contact with a painted surface, as the lead in the paint will conduct. If a wire has to be laid under a floor, it will be easiest to run it along by the joists, cutting in the boards a small hole on each side of the room, running a stiff pilot wire along from hole to hole, and drawing along after it the line wire, which is then drawn tight, stapled to the joist, and the floor made good. If this cannot be done, a floor board may be taken up, saw kerfs made in the top of each joist to serve as grooves to lay the wires in, and after the lines have been laid, the board screwed down. Some fitters bore holes through the joists 2 in. from their top edge, and pass the wires through these holes. This is necessary only where cables, or a large number of line wires, have to be provided for. Wires should not be laid near hot-water pipes, nor where soapy water or other liquid can reach them, nor where oil or grease can come in contact with the covering, as these are liable to penetrate the cotton, dissolve the rubber coating, and corrode the wire.

CHAPTER III.

WIRING FOR ELECTRIC BELLS.

WIRING for electric bells comes under two headings: (1) Surface work, which is done after the house is finished, and consists in fixing the wires to the surfaces of walls and partitions by means of staples. (2) Tube and casing work, which should be commenced as soon as the new walls of a house are up and the roof is put on, as the tubes must be behind the plaster or buried in it. In tube work, either the lengths of tube are threaded on the wires and the two are secured to the walls together, or all tubes, boxes, and plugs are fixed to the walls first, the line-wires being drawn through them as required. If zinc tubes are employed, it will be advisable to choose those of not less than ½-in. diameter, and thus give room enough to draw in the line-wires easily. It may be necessary to draw other wires in at some future time, or to repair faults in lines; this cannot be done readily if the wires are wedged tightly as they might be in a smaller tube. Although zinc tubes are light and cheap, they have the disadvantage of being liable to damage the insulation of the wires. Wood casings are used as a protective covering, but are liable to absorb moisture and become rotten. They also take up much space unless chases are cut in the brickwork. They should be made from close-grained wood, and after being shaped should be saturated with a damp-proof preservative compound, similar to that employed for insulating braided wire.

An improvement on the zinc tubes and wood casings, however, are the strong insulating paper tubes, manufactured by a special process, which renders them durable, *waterproof, internally* smooth. and practically fire-proof.

They are made in three grades—plain, brass-armoured, and iron-armoured. Plain tubes may be used for surface work along chair-rails, skirtings, and dadoes, as the material can be sized, varnished, or painted to match existing decorations; or they may be bedded like zinc tubes in ordinary plaster. Brass-armoured tubes are for use in moist situations, or where caustic cements are likely to injure the prepared paper. Iron-armoured tubes are mechanically stronger than brass-armoured tubes, and afford complete protection to wires in wet situations.

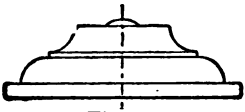


Fig. 6.

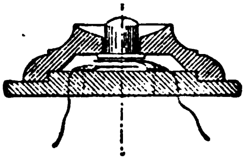


Fig. 7.

Figs. 6 and 7.—Elevation and Section of Electric Bell Push.

All grades are made in 10-ft. lengths, and each length is provided with a socket or coupling. Bends and elbows to turn corners are also supplied, and intersection boxes of the same material are provided to facilitate branch-line connections. These tubes are made in several sizes upwards from ½ in. in diameter.

An electric circuit is made in sections, and is provided with appliances for bridging gaps. When the gaps are unclosed the circuit is said to be open; but when the gaps are bridged, the circuit is said to be closed. The appliances in general use for closing an electric-bell circuit are named "pushes," because the circuit is closed by *pushing* a stud into a hole left in the centre of each appliance. The illustrations, Figs. 6, 7, 8, and 9, show how these pushes are made, and how the circuit

is closed by pushing in the central stud. An ornamental box of turned wood, china, or metal, provided with a screw-on cover, is furnished with a fixed quadrant, and

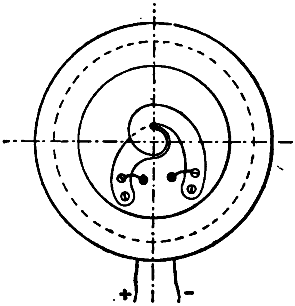


Fig. 8.

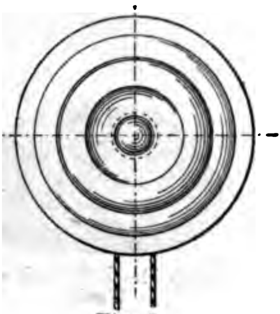


Fig. 9.

Fig. 8.—Plan of Push showing Internal Fittings. Fig. 9.—Plan of Complete Push.

a spiral spring of brass or German silver, shaped as in Fig. 8 or Fig. 10. One of the branch lines is connected to the quadrant, the other line to the base of the spiral spring. The space between these two pieces of brass

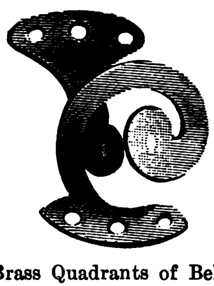


Fig. 10.—Brass Quadrants of Bell Push.

forms the gap, which is bridged by pushing an ivory or bone stud resting on the top spring, thus pressing the spiral spring on the quadrant below. These pushes may be obtained ready made—in wood, china, porcelain,

levers mounted on blocks of polished wood, slate, or porcelain, fitted with metal studs (see Figs. 20 and 21) and are connected to parts of the electric-bell system.

Most of these appliances are intended to be attached

Fig. 18.—Electric Bell Pull.

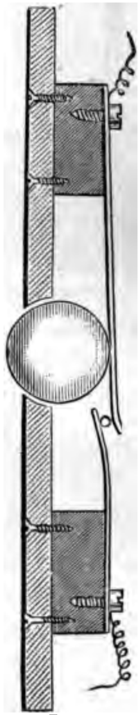


Fig. 19.—Burglar Alarm Contact.

to walls, doors, etc., exposed to full view. It is therefore desirable to provide some means of fixing them to walls in connection with line-wires, and also to make arrangements for their removal when repairs are required. When electric-bell wires are fitted as surface work, it is necessary to fix the pushes to some existing

woodwork, or to cut away brickwork, let blocks of wood into the walls, and fasten the pushes to these by means of screws. When tube and casing work is employed, blocks of wood, such as elm or beech, are nailed to the brickwork wherever pushes have to be fixed, and the set of tubes or casings end in these blocks. Figs. 22 and

Fig. 20.

Fig. 21.

Figs. 20 and 21.—Two-way Switches.

23 show how these blocks should be made. The base of each should be not less than 3 in., with the edge of each block bevelled off to leave a top fully 2½ in. in diameter. The thickness must be determined by the diameter of the tubes and the thickness of the plaster, as the face of

Fig. 22.

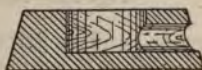


Fig. 23.

Fig. 22.—Round Push Block. Fig. 23.—Section of Push Block.

the block should be flush with the finished plaster. A central cavity, at least 1¼ in. in diameter, must be cut in each block, and a transverse hole to meet this from one side must also be cut for the entrance of the end of the tube and wires. If the conduit system of insulated paper tubes is employed, special hardwood blocks can be purchased ready for use.

The tools, etc., generally required for electric-bell work include a keyhole or compass saw or a set of steel saws and pad, a small tenon saw, one or more firmer chisels, one cold chisel, two small gimlets, two bradawls (fine and coarse), two screwdrivers (large and small), one long bell gimlet, a good brace with set of centre-bits and drills and a long brick drill, one or two hammers, a pair of taper-nose cutting pliers, a pair of pincers, an 8-in. half-round file, a soldering bit, some tinman's solder and some resin, a strong pocket-knife, a 2-ft. rule, a standard

Fig. 24.—Circular Wire Gauge.

wire gauge, and a galvanometer. To these may be added a ratchet brace for drilling holes through joists, under floors, and in other cramped situations, where an ordinary brace cannot be used.

The electric bell fitter will have to deal with a variety of materials used in building, and must know how to cut these away and make good all damages and defects. He may have to work within an hour in metals, stone, brick, plaster, and wood, and must therefore have suitable tools to deal with all these materials. It sometimes happens that a wire has to be passed through a wall, and then a brick drill or cold chisel will

be required; or the wire has to be led down from one floor to another, when the long bell gimlet will be needed. Holes will have to be cut in floor boards for the purpose of drawing wires along between the joists, and here the small saw will be useful; repairs in woodwork will necessitate good joints, and a tenon saw and firmer chisels will be needed to make them.

A wire gauge will be often wanted to determine the size of wire to be used, and a "standard" gauge is recommended; its measurements will also show the Birmingham wire gauge near enough for all practical

Fig. 25.—Detector Galvanometer.

Fig. 26.—Pocket Galvanometer.

purposes. The gauge shown by Fig. 24 is a handy form. A galvanometer is also necessary; its purpose is to show whether an electric current is passing through a wire or not. Linesmen's detector galvanometers are shown by Figs. 25 and 26. A testing-set with battery complete is illustrated by Fig. 27.

All joints in electric bell line wires must be soldered. If the ends of the wires are merely cleaned and twisted together, the bell may ring whilst the joint is new; but damp air soon corrodes copper and forms copper oxide, which interposes between the laps or spirals of wire and increases the resistance of the joint.

The form of joint for electrical wirework is very important, so illustrations are given of badly made joints; also of one properly made. The ends of the line-wires to form the joint must be made quite clean by

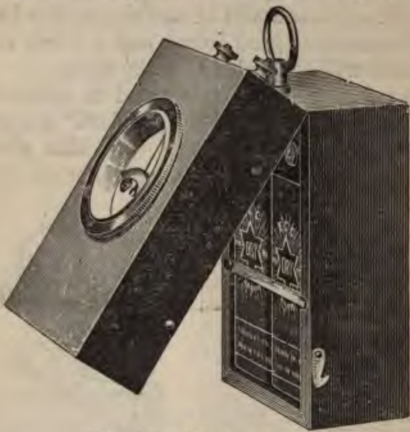


Fig. 27.—Testing-set.

first stripping off all the insulating covering, and then rubbing the bare wires with emery-cloth. The two cleaned ends must be rubbed with resin and coated with

Fig. 28.—Crossed Ends of Wires.

solder, then crossed, as shown by Fig. 28, the left-hand end being wound tightly around the wire to the left, and the right-hand end to the right, as shown by the finished joint, Fig. 29. A little resin or candle grease is then

rubbed on the joint, an assistant holds the wire firmly in his hands, with the joint between them, and the wire is made hot by rubbing it with the hot soldering bit; a drop of solder is then applied to the joint, which will run between the spirals of wire and solder them firmly together if the wire has been properly prepared and the joint is hot enough. Resin or composite candle or paraffin wax should always be used as a flux for soldering

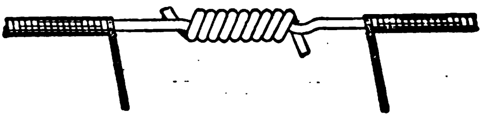


Fig. 29.—Well-made Joint in Wires.

electric wire joints. Soldering fluids of any kind cannot be trusted, because they corrode the wire after the soldering is done, and thus make a bad joint. Some fitters prefer using a soldering bit with a notch filed in it, as shown at Fig. 30; the joint rests in this notch, which also holds a bead of solder ready melted. Others rest the joint on a piece of firebrick or a fireclay lump whilst soldering it. Expert workmen use tallow and

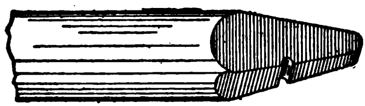


Fig. 30.—Copper Bit for Soldering Wires.

rushes and a blowpipe, or a spirit lamp and a blowpipe, or a blowlamp, to heat the joint; but there is always a risk of scorching or burning the insulation on each side of the joint, or melting the composition or rubber and getting it into the joint, when a lamp flame is used direct. The flame may be employed to heat the soldering bit, or this may be made hot in a charcoal fire or in an ordinary fire.

When heating the soldering bit, care must be taken not to burn off the solder or "tinning." If this is accident-

it may be necessary to add another cell to the battery, connecting the two cells in series as shown by Fig. 38. Where the bell cannot be attended to at once, the indicator shows by a mechanical movement the push used; or bells of different tones may be employed, the

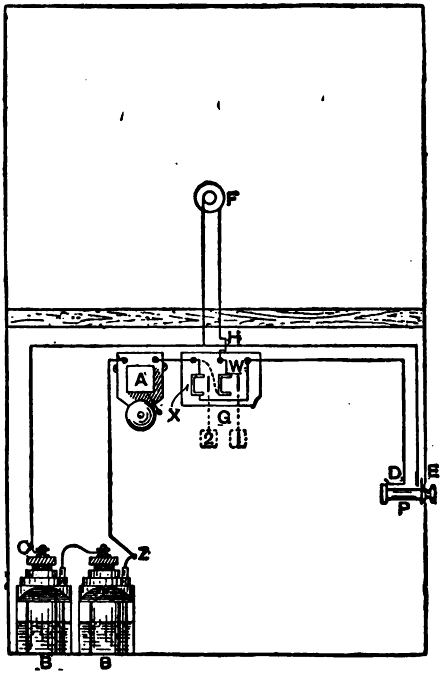


Fig. 38.—Double Electric Bell Circuit with Indicator.

connections being as in Fig. 39, the letter references in which are the same as in Fig. 38.

In the case of a house with three floors and basement, an extension of the system is necessary, as means must be provided on each floor for ringing a bell. An indicator must also be fixed near the bell, to denote the

floor from which the bell is rung; a separate line must be provided for each floor, and therefore some alteration must be made in the wiring. It is not necessary, however, to have two line-wires running the whole height of the building; one main line-wire, usually named the return wire, may run from the battery direct to the topmost floor. It is advisable to have the wires covered with at least four different colours or combinations of colours, and to choose for the main wire one of these, which then can be recognised in any part of the building.

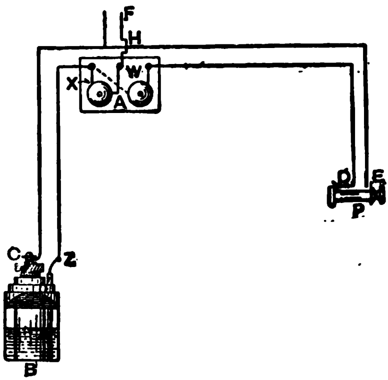


Fig. 39.—Double Electric Bell Circuit with Chime Bells.

A diagram of connections for a system with five pushes is shown by Fig. 40. The line from the front door pull goes to No. 1 stud on the indicator board, round No. 1 magnet and movement, then by a branch wire inside the case (shown by a dotted line on the diagram) to the main stud, round the bell magnet to the zinc element of the battery, through this, and back by a branch from the main line at C to the pull. The circuit from the first floor will start from push No. 2, to indicator stud 2, through magnet and movement 2, bell and battery, then back by main line to the push by a short branch line connected at D. The circuits through

CHAPTER IV.

ELABORATED SYSTEMS OF WIRING; BURGLAR ALARMS.

HITHERTO only plain and simple systems of wiring have been dealt with; attention must now be turned to more complicated arrangements.

A system may be desired with a bell in each room, and with provision for ringing each bell singly and separately from one push, so that at will the occupant of any room can be summoned to attend a particular place. This requirement is fulfilled by means of one main line running from one terminal of the battery to all these bells, and a branch line from each running to a switchboard, as shown in the diagram, Fig. 63. With the form of switch shown a wire connects the pivot stud of the switch to one quadrant of the push, and a branch line from the other quadrant is run to the other terminal of the battery. Then, when the switch lever rests on the contact piece 1, bell No. 1 can be rung by pressing the push. By moving the switch lever to contact piece 2, bell No. 2 may be rung, and so on. If an answering signal is required from each room, it will be necessary to put up bell No. 4 in the office, and connect this with the battery and a set of pushes, as shown on the right-hand side of the diagram (Fig. 63).

Two or more bells may be rung at one time from one push, by connecting the bells in series, as shown to the left of Fig. 64. The push is connected to one terminal of a bell, a line is connected to the other terminal and carried on to the next bell, and so on through the whole set of bells. The electric current then traverses the whole series of bells at the same time. If the bells are all of the single-stroke pattern, or made to short-circuit the coils at each stroke, or differentially wound

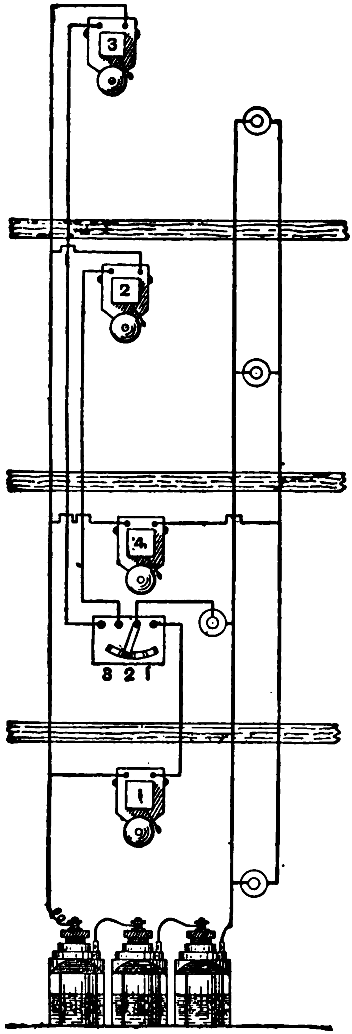


Fig. 63.—System for Ringing Bells Separately from Push and Switchboard.

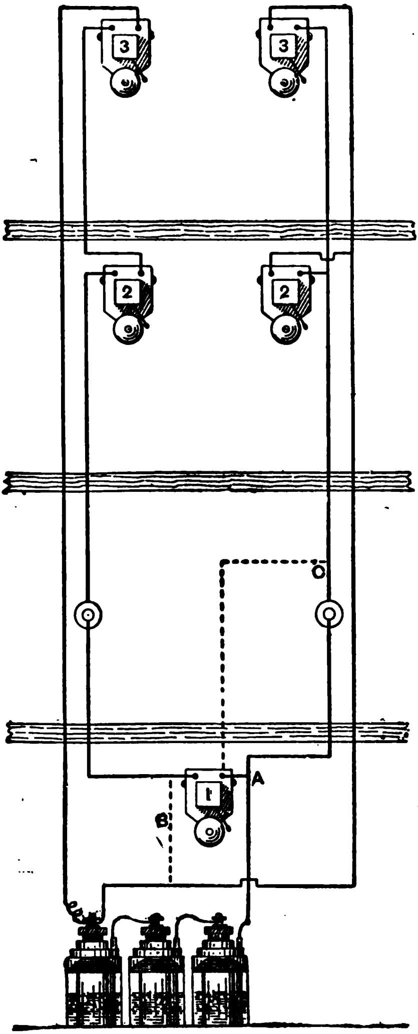


Fig. 64.—System for Ringing Bells Simultaneously from One Push.

to work on such a circuit, there will be little difficulty in adjusting them to ring all at the same time. But if the bells are of the ordinary trembling or vibrating type, they will not ring in a satisfactory manner, because their vibrating parts do not make and break contact in unison. This difficulty may be overcome by unscrewing the contact studs of bells 2 and 3, disconnecting the wires from the contact pillars, and connecting the lines direct to the magnet coils, thus making them single-stroke bells. Bell No. 1 is left intact, and, as its vibrating part makes and breaks contact, it governs the movements of the other bells. When bells are thus arranged, the circuit is through all the magnet coils in succession, and as each coil is of high resistance the total resistance of the circuit is thereby increased. To overcome this extra resistance it will be necessary to add cells in series to the battery.

There is still another method which may be adopted for ringing two or more bells simultaneously. This is shown on the right-hand side of the diagram, Fig. 64, where the bells 2 and 3 are connected in parallel, that is to say, as so many bridges spanning the lines. If bell No. 1 is to be included in this arrangement, it must be disconnected at A, and a line run from this terminal, connecting it above the push at C as shown by the dotted lines. The opposite terminal must also be connected by a wire, as shown by the dotted line B. When bells are thus connected, the resistance of the line is very much reduced, because each magnet coil provides an additional path for the current, which then divides in an inverse proportion to the resistance of the coils. The coil with least resistance will therefore have a larger share of the current than a coil with a higher resistance, and, as a consequence, a louder tone will be obtained from the low-resistance bell. In some cases the high-resistance bell will not ring at all.

To equalise the tones, it will be necessary to have the bells as nearly alike as possible, and all the circuits of equal resistance. If this cannot be done conveniently,

put the bell with least resistance on the longest circuit, and add resistances in the form of short pieces of iron wire, to the other circuits, until the tones are equalised

As a rule, bell-ringing batteries, such as the Leclanché, Gassner, and other dry cells, and the Daniell, work best with small currents, for when the current is large the cells rapidly polarise. It is therefore necessary to have larger cells, or to couple the smaller cells in parallel, as the bells are connected.

The cells of a battery are coupled in series, when the zinc of one cell is connected to the carbon of the next cell. When the zincs of all the cells are connected to one line-wire, and all the carbons to the other line-wire, the cells are coupled in parallel.

Larger houses than those that have been dealt with may be wired on principles similar to those already explained; the plans, extended and amplified, are adaptable to all ordinary circumstances. It will be advisable in all cases to draw on paper a diagram of the lines, bells, indicators, pushes, and connections, before the tubes are fixed or the lines laid. The following method of drawing these diagrams may be useful: First indicate the battery in a conventional manner, using thin vertical strokes to represent the zincs and thick vertical strokes to represent the carbons; do not attempt to represent the cells pictorially. Then show the bells in their positions. These may be represented by small squares inside larger ones, with two dots to show the position of the terminals. Next show the position of the pushes by small circles within larger ones, and the switches by squares with dots for terminals, and an oblique stroke across to represent the switch arm or lever. Then sketch the indicator, as shown in Fig. 65.

This done, draw lines to represent the wires. Run a thick ink line from the carbon of the battery to the farthest point, and call this the carbon main. Complete one circuit from this through one of the bells, then back to the zinc of the battery by a thin line.

Construct the others, one by one, in a similar manner, using coloured inks or crayons of differing tints to represent different circuits. Then go over the whole, and shorten some of the branches, and combine wires

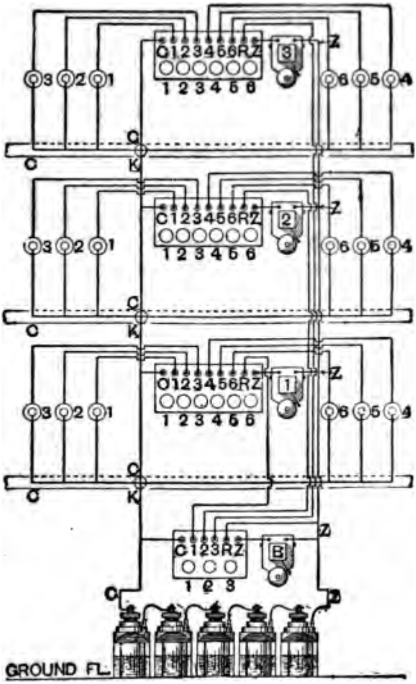


Fig 65.—System of Wiring Mansion or Hotel for Electric Bells.

where practicable, with a view to economy without impairing efficiency.

Note, however, that a separate return wire must be run from every push to its corresponding number on the indicator, and from this to the return wire leading to the battery, as shown in Fig. 65, which represents a

system of wiring suitable for large establishments. In this arrangement, a bell and indicator are fixed on a wall on each landing of the staircase, to represent the rooms on each floor, and another indicator is fixed in the usual place on the ground floor to show the floor from which the signal has been sent. Each indicator is furnished with a relay, which throws the bell attached to it, and also the bell on the ground floor, into circuit with the battery when one of the pushes on that floor is pressed. The action of this relay is shown in the diagram Fig. 66.

Taking the first floor as an example, when the push-button 1 of No. 1 room is pressed the current goes from C through the push to stud 1 (see Figs. 65 and 66), through the movement of the indicator

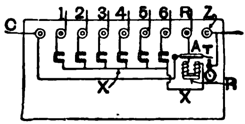


Fig. 66.—Diagram of Indicator and Relay Connections.

by X to the relay coil R, and, by magnetising the core of this relay, pulls down the armature A from its position of rest against the stud T to the stud O below. The current then finds an easier path by way of the terminal C across A to O, then to terminal Z, through the bell to the zinc terminal of the battery. At the same time it has moved indicator movement 1 on the ground floor, and rung the bell there also, the connections for this being as shown in Fig. 65. By this means the attendant on the ground floor knows that the signal has been sent from the first floor, and on reaching the landing of this floor, sees by the indicator that the signal has been sent from No. 1 room. The course of the current can easily be traced from all the other rooms by referring to the diagram (Fig. 65).

The system of tubes in this arrangement (Fig. 65) is simple and economical. The main conducting wire C runs

from the ground floor to the top of the building, branching off at K to each room on the respective floors. Intersection boxes should be provided at these junctions, and enough slack wire left in them to take up in after repairs. The branch wires may be laid along under the floors, and then through tubes to the pushes. The return wires are shown overhead, to avoid confusion, but these may be brought down tubes in the usual manner, and under the floor to the stairway. The main wire and its branches to the push should have a distinct colour of covering. The other branches and return wires should also each have a distinct colour. A light, ornamental wood casing, with as many grooves in it as wires, and a cover secured by screws, will be the best protection for lines on the stairway. The wires may be led through these, right up to the bell and indicator.

It will be readily understood that the danger of cross leakage from line to line increases with the number of battery cells in series, because the electromotive force is higher, and it is therefore necessary to be more careful of the insulation, and to well separate the line-wires by some good insulating substance where the main and return wires unavoidably cross each other. With increased length of line come also increased resistance and the necessity for the use of larger wires, say No. 18 S.W.G. for the main and longest return branches, and No. 20 S.W.G. for the rest. In all cases use only best indiarubber double-cotton covered, paraffined wire, or that having a braided and compounded insulation.

Three diagrams of wiring for special purposes are given as examples in Figs. 67, 68, and 69. Fig. 67 supposes the existence of two bells and two pushes, with only one battery. It is desired to send signals from one building to another, and to have replies sent back; three-line wires must therefore be used, and the connections made as shown in the diagram. Fig. 68 supposes the existence of the same two bells and battery cells, with only one line-wire. To meet this case, either use two Morse ringing keys or a pair of double contact

pushes, and connect the whole together as shown in the diagram, using the gas or water pipe as a return path for the current. Fig. 69 supposes the bell to be too far away to be easily rung with the battery power at hand. In this case, put one cell close to the bell, connected through it by a relay. Adjust the relay to work with the remaining cell, as shown in the diagram, using the gas or water pipes in each building as the return path for the current.

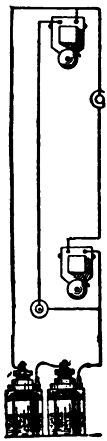


Fig. 67.—System of Two Bells and Pushes.

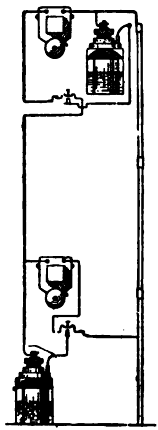


Fig. 68.—System of Ringing Two Bells over One Line and Gaspipe.

Electric bell fittings should always be tested as the work is proceeded with. The testing can be done after the work has been completed if preferred, as directed below, using the battery to be employed in ringing the bells; but it is best done piece by piece with a portable set, such as that illustrated by Fig. 27, p. 42. If zinc or other metal tubes are employed, it will be advisable to connect one wire of the testing-set to each line-wire in succession, whilst the other is held *in contact* with the metal tube. If the wire is bared of

its insulation and is in contact with the tube, the leakage will be shown by a deflection of the galvanometer needle. Next test the insulation of the branch and main wires by connecting them in couples to the testing-set.

When the installation is completed, and all is ready for working, it will be advisable to test every part, first to prove that the parts are all in working order, and secondly to discover any faults in the insulation. This

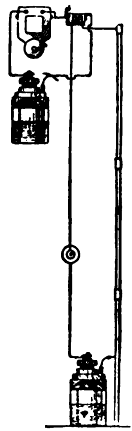


Fig. 69.—System of Ringing Distant Bell with Relay and One Line.

may be done with the battery of the testing-set, or with the bell battery. The solution of sal-ammoniac should be put in the cells of a Leclanché battery several hours before the battery is required for use, so as to get the porous cells well soaked with the solution. When this has been done, each cell should be tested separately, by connecting the zinc and carbon elements to the fine wire coil of a galvanometer or linesman's current detector. As these instruments differ very much in their make and the marking on their dials, directions cannot be given for calculating the value of the needle's deflections.

For all the cells the readings should be the same on the same instrument; if they are not the faulty cell will give the lowest reading on the galvanometer scale. The instrument having three terminals, so that it can be used for "intensity" or for "quantity" of current, next connect the cells one by one to the coarse wire coil. This is a better test than the other to deflect the needle, as it needs a stronger current when passing through the coarse coil of wire. Next, test the cells coupled together in pairs, and thus find out the condition of their connections. An imperfect connection will offer resistance and reduce the current.

The force of electric current obtainable from a battery cell will be controlled largely by the size of the cell and the condition of its contents. A small cell will have a higher internal resistance than a large cell; but cells of the same size should give nearly the same current on the same circuit if their contents are in good condition and the connections are clean. A Leclanché cell in good condition will give an electromotive force on open current of 1·6 volts. If its contents are partly exhausted, the voltmeter may record a reading below 1 volt.

When the battery is right, test all the bells, indicators, relays, and pushes. Disconnect one of the line wires from the battery, connect it to the fine wire coil of the detector, and put this in circuit. If there is a leakage, or if any of the pushes are making contact, the needle of the detector will be deflected. The fault must be found and repaired before further tests are made, because even a small leakage will soon run down a bell battery. Again connect the battery to the lines, and test the ringing capabilities of each bell and the working of each indicator. In this work it will be advisable to have an assistant to go from room to room, following a prearranged plan, and ring each bell, whilst the fitter notes the action of the bell and the indicator. If an assistant cannot be secured, each push must be successively visited and pegged down in contact whilst the bell and indicator are adjusted. When doing this, it will be

advisable to employ only a few of the battery cells in series, and to so adjust bells and indicators as to work them with a low battery power. This will leave a margin of power, when all the cells are connected, to compensate for subsequent wear and tear, and consequent increased resistance.

If a bell does not ring satisfactorily, first see to the adjusting screw of the contact pin. Loosen this, and move it closer to the armature spring, or farther away, as may be required. If the spring is too stiff, bend it towards the armature a little. A pin that is very thin and sharp-pointed offers too much resistance, and must be blunted. See that all the connections between the ends of the wires and the screws or terminals are good and quite clean. The armature may seem to stick to the magnet cores when these are hard and thus retain magnetism after the circuit is broken. To remedy this, either stick with gum or paste a bit of paper to the inside of the armature or to the core ends, or drill holes in them and insert two brass pins. If the poles of the indicator magnets, or those of the relays, are affected in a similar manner, adopt the same means to remedy the defect. If the clutch of a mechanical throw-back indicator holds the arm of the movement too tightly, it may be necessary to smooth the parts with a fine file until they work more freely. Attention must also be paid to connections here, as throughout the circuit these should be clean, and must not be loose. Similar attention must be given to relays and their adjustment. Electrical replacement indicators may give much trouble in adjustment before they work well; they should always be set true by the aid of a spirit level before the adjustment is made.

Imperfect connections between the working parts of pushes, pressels, and pulls frequently cause bad performances in the bells and indicators, for a bit of dirt, grease, or grit between the contact surfaces will cause a break in the continuity of the circuit. Badly made pushes will corrode at the points of contact, especially in new

houses and other damp situations. The springs of common pushes also lose their elasticity and get out of set. This is a trouble more frequently met with in pulls, where it is liable to cause short circuit and a consequent continuous ringing of the bells. The connections may also be loose and corroded, the latter fault following the use of untinned copper wire, and of damp push blocks under the pushes. As faults are likely to

Fig. 70.—Continuous Action Electric Bell.

be traceable to these points, they should receive first attention, and the defects should be made good before seeking elsewhere on the circuit for evils.

Electric bells are employed for many purposes besides those of announcing visitors and summoning servants. They are found useful in announcing the intrusion of burglars and giving an alarm in case of fire. For these purposes the mechanism of the bell is modified, and so connected with a battery

as to ensure continuous ringing after it has been once started; or an electro-magnetic arrangement, named a relay, is placed in the main circuit to automatically switch in, when the main circuit is closed, a local battery attached to an ordinary vibrating bell. Fig. 70 represents the internal mechanism of a continuous-action electric bell, the cover being removed. The lever, attached to a cord on the right, is kept from con-

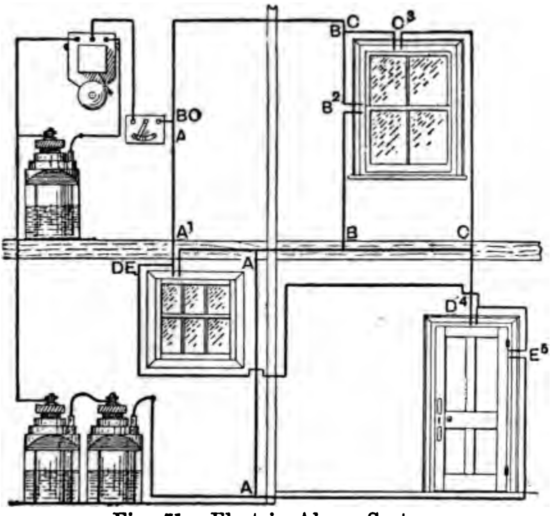


Fig. 71.—Electric Alarm System.

tact with the brass pillar below it by a stop on the end of the armature. When one of the alarm circuits is closed, current from the main battery passes through the magnet coils and magnetises the cores, which then pull the armature away from the lever. This then falls on the brass pillar, and closes the circuit of the local battery at the same time as the circuit of the main battery is broken. The bell will start ringing and continue to ring until the local battery is exhausted, or until the cord at the side is pulled to reset the lever, and

and this presses on the contact pin when the sash is closed. A window cannot be left even slightly open when these contacts are used, unless the special switch is on the "off" position, as the sash must be quite closed and fastened to press in the pin and keep the metal surfaces apart. All such contact pieces or circuit closers must in order to work well be accurately fitted.

A system of burglar alarm contacts may be arranged to work on a principle exactly the reverse of that just described. All the contacts are made to close the main

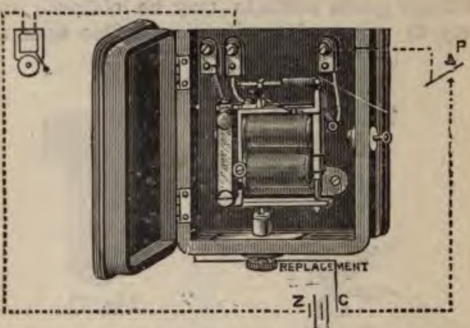


Fig. 75.—Relay for Closed Circuit System of Electric Alarms.

circuit of a specially constructed Daniell battery, when the doors and windows are closed, and thus maintain a constant current flowing from the main battery through the coils of a magnetic relay, the armature of which forms a link in the local battery circuit connected with the bell. As long as current flows through the coils of this relay, its armature is prevented from closing the local circuit. Should a window or door be opened, or one of the line-wires be cut, the main circuit is at once broken, and the armature of the relay closes the local circuit. Fig. 75 represents a relay of this kind connected to an electric bell, with an arrangement underneath for replacing the armature. The wiring will be

precisely the same as for other electric alarms. If an indicator is desired by a bedside to show which door or window has been left open or forced by a burglar, the system of wiring must be the same as that for connecting several rooms with an indicator, each door and window being treated as a separate room by leading a branch line from one of the contact terminals to a corresponding stud on the indicator.

CHAPTER V.

BATTERIES FOR ELECTRIC BELLS.

PRIMARY cells are usually employed to ring electric bells of the ordinary type, but in special situations and for special purposes, as in connection with a telephone system, the bell is rung from a magneto-electric machine. In each cell of a battery there are two elements—one, named the positive element, which is consumed to furnish electric energy, and the other, named the negative element. Zinc is the positive element in general use in electric-bell batteries. Carbon is generally employed as the negative element; but copper is sometimes used instead, as in the Daniell and the Edison-Lalande batteries. These elements are usually held in two separate vessels—one made of porous earthenware, the other of glass, stoneware, or other impervious material. Two or more cells constitute a battery for ringing electric bells. Any type of battery may be used, but only a few types have proved thoroughly suitable.

When heavily worked or overworked, either by frequently ringing the bells, keeping them in action for a long time, or allowing a leakage to continue in the circuit, the battery fails to ring the bell, because its own elements offer a high resistance to the current. The internal resistance varies with the size of the cell, being lowest in large cells and highest in small ones. The internal resistance also varies with the quality of the materials employed in making the cell, and is influenced according as the cell has been much or little used. The choice of a battery is therefore a most important matter, and only cells of the largest size and best make should be used in large installations, the smaller sizes being suitable for single bells only.

Without doubt, the most popular cell for electric-bell work is the one invented by Georges Leclanché; this cell, which is named after its inventor, has withstood the test of many years, and can be confidently recommended. There are, however, other cells which, though generally considered inferior to the Leclanché, yet answer their purpose well, and these, together with the latter, will be noticed in this chapter.

Leclanché cells are sold in three sizes usually, as shown in the following short table:—

Size.	*E.M.F. in Volts.*	*Internal Resistance in Ohms.*
3 pints	1·60*	·75 — ·85
1 quart	"	1·10—1·20
1 pint	"	1·50—1·60

The outer containing jar is almost always of glass, and square, for convenience of packing to form a battery (see Fig. 76), with a large round mouth furnished with a lip. The cell complete has the top of the mouth, both inside and out, for about an inch down, coated with Brunswick black, paraffin wax, or similar material that will prevent the salts formed by the contents from creeping over the edge. This coating is applied by thoroughly cleaning the jar, heating it, and either dipping the rim into melted paraffin wax, or giving it two or three coats of Brunswick black.

The porous pot which goes inside the glass jar contains a carbon plate with a lead cap, on which is a binding-screw with connections. The whole of the space between the carbon and the pot, to within ½ in. of the top, is filled up with a mixture of equal parts by bulk of crushed coke or carbon and peroxide of manganese, crushed to the size of very small peas or rice grains, sifted from the dust and packed in as tightly as

* Prof. Ayrton gives this as 1·47.

possible. So as to allow the gas formed in working to escape, two little pieces of glass tube are embedded in the mixture on each side of the carbon, and then the top should be sealed up with melted pitch, or pitch and resin mixed; the top of one tube is shown in Fig. 76. The whole of the top should have two or three coats of Brunswick black, working well over the lead cap and

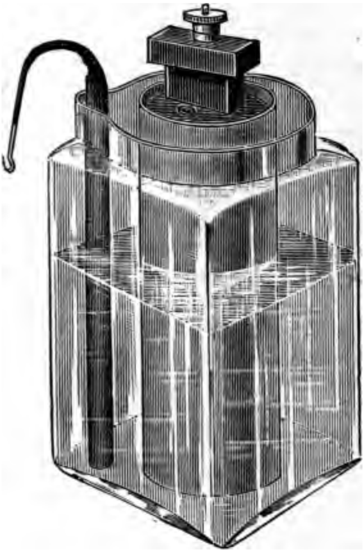


Fig. 76.—Leclanché Cell.

into the top of the carbon plate, and down the outside of the top of the pot for about 1 in.; dip the bottom of the porous pot for about ¼ in. into melted paraffin wax, and the negative element is ready for use.

The positive element is generally a rod of drawn zinc, if cast it is crystalline and brittle. A hole should be drilled in the top, and a stout piece of guttapercha-covered copper wire either screwed or soldered in. The joint should be well covered with gutta-percha or several

coats of Brunswick black. The zinc should be amalgamated by the following method. With a file remove rough excrescences, etc., and have ready two glass jars deep enough to take the zincs; one of these should be half full of water containing about a teaspoonful of sulphuric acid, the other a quarter full of the same mixture with a little mercury at the bottom. Dip the rod first in the tube with the acid and water to clean it well, then into the one with the mercury, and by holding it in a slanting position the mercury can be easily flowed all over the zinc by twisting it round. Wipe off the superfluous mercury with a rag, and the rod is ready for use.

To charge a Leclanché cell, three parts fill the outer jar with a strong solution of ordinary sal-ammoniac; if the jar is filled more than this, the salts of the solution will creep up. In a few hours the cell will be ready for use. Should it not be convenient to wait, pour through the little glass tubes in the seal some of the solution into the porous pot, and the cell will be in working order in a minute or so.

The chemical action that goes on during the working of the cell is this: The zinc, sal-ammoniac, and peroxide of manganese are changed into zinc chloride, water, and ammonia; and the oxide of manganese is reduced to an oxide less rich in oxygen. Using chemical signs, Zn, $2NH_4Cl$, and $2MnO_2$, become $ZnCl_2$, H_2O+2NH_3, and Mn_2O_3.

Where a good, full current is wanted for short periods at intervals—such as for electric-bell work—a cell of this type is suitable; it is of no use where continuous currents are needed, as it polarises quickly, recovering itself, however, equally rapidly. It has another advantage—action does not go on inside the cell unless the circuit is closed and the cell is doing work; therefore it can stand for months always ready charged without any fear of the zincs being eaten away; moreover, it is not affected by changes of temperature, and does *not give off* noxious fumes. These facts make it of

the greatest use for bell-work, etc.; but for lighting, driving motors, and similar work with which this handbook is not concerned, it is practically useless.

The Leclanché battery has undergone several changes, and in one form the porous cell has been replaced by solid blocks of manganese and carbon clasped tightly to the carbon element by rubber bands. This is named the Agglomerate Leclanché. In another form the carbon element is fluted and surrounded by six of these agglomerate

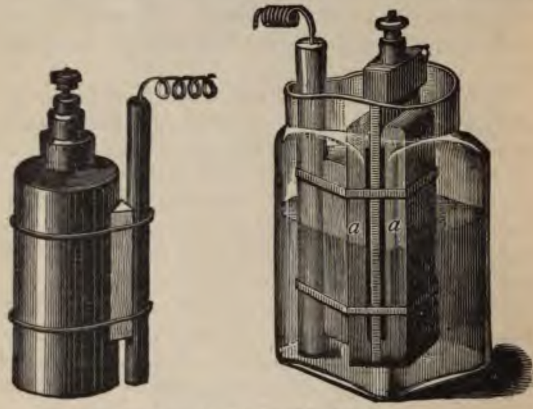


Fig. 77.—Agglomerate Leclanché Cell.

blocks, thus still further reducing the internal resistance. In another form the position of the elements is reversed, the zinc rod being placed in the porous cell. In another (the Victoria Leclanché), the zinc element is used in the form of a plate in a rectangular cell. Neither of these has superseded entirely the original form of the Leclanché cell. A comparatively new departure from the old style Leclanché cell—named the Carporous, or central zinc Leclanché—has the agglomerate block for each cell in the form of a porous cell, in the centre of which the *zinc element* is suspended. The internal resistance is

thereby reduced to ½ ohm in the large sizes, and to 1 ohm in the smallest size.

An agglomerate Leclanché battery is of simple construction and can be easily made. Fig. 77 shows two forms of the negative element, the chief feature being the absence of the porous pot. The mixture is nearly the same, but is made into blocks by using an adhesive medium, and by heat and pressure; one form is a solid block, and the other is two plates *a a*, Fig. 77, one on each side of the carbon. The result is that the internal resistance of the cells is somewhat reduced, as shown by the following table:—

Size.	*E.M.F. in Volts.*	*Internal Resistance in Ohms.*
3 pints	1·55	·50 — ·85
1 quart	"	·60 — ·90
1 pint	"	·80 — 1·10

The zinc or positive element is held in its place by indiarubber rings, and is kept from touching the block by a strip of wood.

In making for home use an ordinary Leclanché cell, stone or glass quart jam jars with large mouths and free from cracks should be thoroughly cleaned and waxed, or painted with Brunswick black, as previously described. In place of a porous pot a bag may be used made from a square of good thick close canvas 8 in. by 7 in. Stitch together into the form of a round sack or bag (see Fig. 78) with a round flat bottom. Dip ½ in. of the bottom several times into melted paraffin wax and dip 1 in. of the top into hot pitch and resin. It is not advisable to make the carbon plate; a 7 in. by 2 in. plate can be obtained very cheaply. Next make a small wooden box, the inside dimensions being the size of the lead cap required; screw on one side so that it can be removed when desired; hold the end of the

carbon plate in the middle of the little box, and fill up with molten lead. A great number of heads can be cast in a wooden box like this before it is burnt up. While the lead and the top of the carbon are quite hot, give them a coat of Brunswick black, working it well into the joint, and down the carbon for about an inch below the lead. It is at this joint of the lead and carbon that the creeping salts do damage and eat away the cap. Now drill the cap and screw in a small binding screw, or solder on a length of guttapercha-covered copper wire; screws are better than solder, as the latter is apt to decay

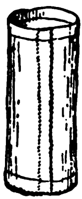


Fig. 78.

Fig. 79.

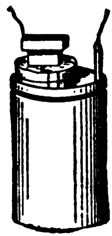


Fig. 80.

Fig. 78.—Canvas Bag for Leclanché Cell. Fig. 79.—Zinc for Leclanché Cell. Fig. 80.—Home-made Leclanché Cell.

under the action of the salts. Pack and seal the bag with the mixture before mentioned, coat with Brunswick black, and the negative element is ready for use.

A drawn zinc rod, amalgamated as before described, should be used; but shift can be made by using a strip of rolled zinc $\frac{1}{8}$ in. or thicker, 7 in. long by 1 in. wide. Drill a hole through the top and slip the end of the wire through and twist it up, then solder, and cover the joint with guttapercha (see Fig. 79), making a joint not likely to give way. The zinc strip should be amalgamated in the same way as the rod. Charge the cell with sal-ammoniac solution the same as for an ordinary Leclanché, and it will work in a very short time. Fig. 80 shows this home-made cell complete; two such lls, if carefully made, will ring a $2\frac{1}{2}$-in. or 3-in. bell.

It is usual to keep Leclanché cells in a wooden box, which protects them from accidental damage, and from dust. The box may be securely covered, and the wires brought out through the back or side. Often the cover and one side of the box are hinged to each other and to the bottom, the cover opening from the back. When constructed in this way, the cover and side fall down when opened, and allow free access to the cells. Such a box is suitable for a Gassner battery (to be described later), but it is advisable to have a thin partition of wood between each cell to prevent accidental contact.

In arranging a suitable place for the Leclanché cells, it should be borne in mind that they work best and last longest when in a moderately cool and dry room, such as a cellar. In hot situations the solution rapidly evaporates, and the salts creep up the sides of the cells and over the connections. If the outsides of the glass cells are allowed to get dirty or are left wet, or stand on a wet shelf, a part of the current will be lost by leakage. Cells must be looked to from time to time, and all causes of leakage stopped; at the same time, the loss of solution from evaporation must be made good by the addition of water; it is not necessary to add sal-ammoniac.

It is a dirty and tedious job to clean and recharge old Leclanché cells. Scrape off from the top of the porous pots as much of the old salts, etc., as possible; then allow the pots to soak, and wash them in warm water to every quart of which has been added a small wineglassful of hydrochloric acid. After that, rinse well in clean water, clean up the binding screws, and give the tops two coats of Brunswick black. Wash and clean the glass containing jars, using hydrochloric acid to remove obstinate dirt. Wash the zincs in hot soda water, and rinse in clean water. Rub them over with a fairly strong solution of sulphuric acid, and with mercury to reamalgamate them, and coat the tops with Brunswick black. Make a saturated solution of sal-ammoniac in warm rain water; if this latter cannot be obtained, use tap water. When cold fill up the outer jars, and leave the

cells to rest for an hour or so before using them. See that the ends of all wires and connections are bright and clean before joining up.

The Edison-Lalande cell, as illustrated by Fig. 81, consists of a tall porcelain jar with a cover of the same material adapted as a support to the battery elements and terminals, the elements being suspended from the top.

Fig. 81.—Edison-Lalande Cell.

The following is a table of sizes in which the Edison-Lalande cell is made.

Size in Inches.	*Capacity in Ampère-hours.*	*E.M.F. in Volts.*	*Internal Resistance in Ohms.*
	CIRCULAR	FORM.	
$3\frac{3}{4} \times 7$	50	0·75	—
$5\frac{3}{4} \times 8$	150	0·75	0·012
$5\frac{1}{2} \times 11\frac{1}{2}$	300	0·75	0·03
$6\frac{3}{4} \times 10$	300	0·75	0·03
7×18	600	0·75	0·03
	OBLONG	FORM.	
$4\frac{3}{4} \times 4\frac{3}{4} \times 7\frac{1}{4}$	40	1·50	—

The Edison-Lalande is a single-fluid cell; the elements are two plates of amalgamated zinc on each side of, but insulated from, a copper frame tightly packed with black oxide of copper. The frame of copper forms the negative element, and the oxide of copper does duty as a depolariser. The cell is filled with a 25 per cent. solution of caustic potash, which is kept covered with heavy paraffin oil.

Fig. 82.—Daniell Cell.

Until the Leclanche battery was invented, the Daniell battery was generally used for bell work, and it is still greatly used in the post office telegraph service.

There are several modifications of the Daniell cell, Fig. 82 showing the internal arrangement of the porous pot form. The glass or glazed vitrified stoneware jar J contains the cylindrical plate C (made of sheet copper), the porous pot P (made of unglazed earthenware), and the zinc rod Z. Inside the porous pot dilute sulphuric acid is poured, while the copper plate C stands in a saturated solution of copper sulphate. The connections are made to

the two wires shown in the illustration. The maximum electromotive force of the cell is about 1·14 volts, with an internal resistance of 3 ohms in the 3-pint size, and 1·6 ohms in the 3-quart size.

To recharge a Daniell battery, thoroughly clean all parts and reamalgamate the zincs; charge the porous pot, containing the zinc, with a solution of 12 or 13 parts of water to 1 part of sulphuric acid, and the outer jar, containing the copper plate, with a saturated solution of

Fig. 83.—Minotto Cell.

sulphate of copper. There should be a small sieve or tray near the top of the containing jar, but below the level of the copper solution; this should have crystals of sulphate of copper in it to keep the solution saturated. If copper is allowed to deposit on the porous pot, the current will fail, not only on account of a higher internal resistance, but also because this short-circuits the cells. To prevent this, the zinc and also the zinc sediment must be kept from touching the porous partitions.

The Minotto cell is a modification of the Daniell cell. As shown by the constructional view, Fig. 83, at

the bottom of the jar J, which may be of glass or glazed earthenware, is placed a copper plate G carrying an insulated copper wire. Crystals of copper sulphate C S rest on this plate, and above them, but separated by a layer of canvas *c*, is a layer of sand or sawdust *s*. Another layer of canvas *c* separates the zinc plate Z from the sawdust. B is the binding screw. To charge the cell, zinc sulphate solution is poured on top of the zinc plate, the sawdust being damped with the solution of zinc sulphate before placing it in the cell. The electromotive force of the Minotto cell is slightly less than that of the Daniell cell.

Fig. 84.—Fuller Cell.

The Fuller cell (Fig. 84) consists of an outside stoneware jar with an inner porous pot, the outer jar having a plate of carbon in chromic acid or bichromate of potash solution, with one-quarter of its bulk of sulphuric acid. In the illustration a part of the porous pot is cut away to better show the zinc. The inner porous pot contains a rod of zinc ending in a plug Z, the bottom of the pot is covered with mercury, the remainder of the cell being filled with sulphuric acid and water. The electromotive force is 1·50 volts.

There are two different charges that can be used for a Fuller cell. In one the porous pot with the zinc plug is charged with a solution of 1 oz. of common salt to 1 pint

of water. In the other a solution of 12 parts of water to 1 part of sulphuric acid is used. In using either of these solutions, about 1 oz. of mercury should be placed at the bottom of the porous pot, to ensure constant amalgamation of the zinc, thereby preventing waste. The outer jar, containing the carbon plate, is charged with a solution made by dissolving bichromate of potash 3 oz. to every pint of warm water, and then adding 3 oz. of sulphuric acid gradually, stirring with a stick. The addition of the acid causes the solution to become scalding hot, so care should be taken to make the mixture in a vessel that will not crack. All the solutions should be quite cold when the cell is put up for use. The size of porous pot will depend on the shape and size of the outer one. It should stand up about 1 in. above the outer pot, and should comfortably hold the zinc plug without occupying too much room in the outer jar.

Superior as the Leclanché is to all other batteries as a source of small intermittent current, it has within the last fifteen years had a rival in the compact little cylinders of zinc known as dry batteries. This name is rather misleading, as the probability is that if the batteries were perfectly dry they would not give current. In some old forms of dry batteries, those of the Silvertown make, for instance, it was necessary to put water in the vent holes before the battery was set in action. In specially dry and warm situations, and when batteries are liable to much jolting and shaking, the Leclanché or, indeed, any fluid battery will rapidly deteriorate. To meet such cases as these, dry batteries are employed.

The Gassner cell (Fig. 85), one of the earliest of dry batteries, is complete in itself, instead of being a composite cell made up of inner and outer vessels. There is no porous cell of any kind, nor any outer cell of glass, porcelain, or other breakable material. The battery case is of thin sheet zinc, which may be made in any form and of any size required; but

the sizes and shapes now in general demand are as follow :—

Oblong cells, $3\frac{1}{2}$ in. × 2 in. × $1\frac{3}{8}$ in.
Circular cells, 7 in. × 3 in.
Oblong cells, $6\frac{1}{4}$ in. × $3\frac{1}{4}$ in. × $1\frac{3}{4}$ in.
Square cells, $6\frac{3}{8}$ in. × $3\frac{3}{8}$ in. × $3\frac{3}{8}$ in.
Oval cells, $5\frac{3}{16}$ in. × $3\frac{1}{16}$ in. × $1\frac{3}{4}$ in.

The sheet zinc case, which forms the positive element,

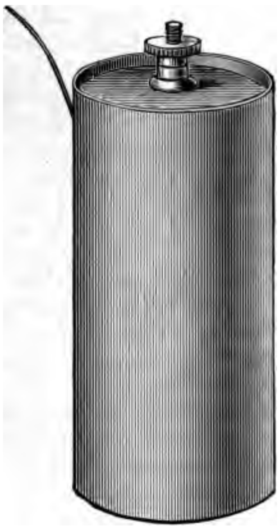


Fig. 85.—Gassner Dry Cell.

is nearly filled with a paste composed of zinc oxide and gypsum, moistened with a solution of zinc chloride. A capped cube of carbon, bearing a binding screw on its head, forms the negative element in the centre of the case, where it is surrounded by the conducting and exciting paste. The whole is sealed over with a composition resembling marine glue. It will thus be seen that there is no liquid to spill, nor is any required, as the paste is moist enough to excite the zinc, and it will

moistened with a solution of sal-ammoniac and zinc chloride; L a white paste of plaster-of-Paris and flour, moistened with a solution of sal-ammoniac and zinc chloride; Z the zinc outer case insulated at the bottom by the millboard case I, though, in the later forms of this cell, this insulating case covers the entire outside of the zinc one; P the bituminous sealing compound; W T the tube by which the gases escape; and T one of the terminals. This cell is made in many sizes and shapes, and is placed in cardboard insulating cylinders, with a label outside, the inner surface of the cylinder being waxed.

The following instructions are for making three of the best home-made dry cells, in what is considered their order of merit:—

Procure a sheet of clean No. 12 zinc, measuring 6 in. by 9 in.; bend this round a wooden pole to make a cylinder 6 in. by 3 in.; cut a circle of zinc to make a bottom, and solder the whole together, with a short length of No. 18 soft-tinned copper wire over the seam to make the terminal from zinc. Next proceed to line this pot with a mixture of plaster-of-Paris or gypsum and sal-ammoniac in the proportion of 4 oz. of plaster to 1 oz. of sal-ammoniac, a few drops of glycerine, and about ½ pint rain water or distilled water. This should be coated over the inside and bottom of the zinc pot to a depth of ½ in.; take a good, close-grained carbon plate 1¾ in. by 6 in. by ⅜ in. thick, drill a hole 1 in. from the top in the centre for the terminal, place a pad of rubber, ebonite, or glass in the cylinder, and stand the carbon plate on it. Pack the intervening space with a mixture of 2 lb. crushed carbon, 1 lb. peroxide of manganese, ⅓ lb. sal-ammoniac, 1 teaspoonful of chloride of zinc, and ½ teaspoonful of glycerine.

This mixture will probably be enough for two or three cells. If the materials are not already damp, sufficient water may be added to make the mixture feel slightly moist. When the mixture has been well mixed and packed in, the cell should be carefully cleaned out

to a depth of 1 in. from the top (great care being taken that the black mixture does not overlap the white), and the space filled up with melted sulphur, or a mixture of melted sulphur and pitch.

The whole cell should now be coated over with black enamel—Berlin or Brunswick black. Add a brass terminal, and wrap paraffined paper round it or, better, use insulating card cylinders, and the cell is complete.

Another dry battery may be made as follows: Make the zinc cylinder of the size required, and procure a carbon plate large enough to leave ¾ in. between it and the zinc pot, and 1 in. at the top; next mix plaster-of-Paris to the consistency of cream, add about one-eighth the quantity of powdered sal-ammoniac and sulphate of zinc in equal proportions, coat the inside of the cylinder with this mixture, and allow this to set; put in the carbon plate, and pack around it a mixture of coarsely powdered oxide of manganese, 5 parts; graphite (carbon), 75 parts; sal-ammoniac, 20 parts; and a little water. Seal up the cell in the manner previously described.

A battery inferior to the last is made by lining a zinc case, made as described on the previous page, with a mixture of plaster-of-Paris, 25 parts; ammonium chloride, 10 parts; and water, 55 parts. The black mixture is powdered graphite, 75 parts; manganese oxide, 10 parts; chloride of zinc, 5 parts; chloride of ammonium, 10 parts; glycerine, 2 parts. Complete the cell by the method already given.

Batteries should be kept in a moderately warm room; damp causes the salts to creep and destroys the connections. A good plan when connecting up cells permanently is to coat the whole of the cells, including the terminals, with hot paraffin wax; this effectually prevents damp salts from arising.

CHAPTER VI.

THE CONSTRUCTION OF THE ELECTRIC BELL.

ELECTRIC bells may be divided into three classes: (1) Single-stroke bells; (2) trembling-stroke bells; (3) magneto-electric bells. Single-stroke bells are those in which the hammer is made to strike the gong once when the circuit is closed, and the number of strokes is controlled by the person closing the circuit. Trembling-stroke bells are those in which provision is made for automatically breaking the circuit after each stroke of the hammer on the gong. When the circuit is closed, the current passes through the magnet coils, as in the single-stroke bell, and thus causes the magnet to attract the armature on the hammer shaft. The movement of the armature breaks the circuit, and thus ceases to attract the magnet. The armature is then drawn back by a spring and closes the circuit, when it is again attracted by the magnet. This to-and-fro movement continues whilst the push button is pressed, and thus gives a rapidly vibrating or trembling movement to the hammer. This form is generally adopted for house electric-bell work. Magneto-electric bells are constructed in a special manner to fit them for being worked by the pulsating current from a magneto-electric machine, the hammer vibrating between two gongs. These bells are sometimes used in hotels and large houses, and where signals are sent between two stations. They are frequently used in telephone circuits, but rarely in ordinary electric-bell installations.

Bells are named after the shape and size of their gongs. Those in general use are dome-shaped; but the sheep bell, spiral steel wire, and church bell forms are

also used in electric-bell gongs. The common grade of English-made bells has the wood back of polished pine, the springs of German silver, and the contacts of silver; whilst teak or walnut cases, boxwood bobbins, filled with No. 26 B.W.G. silk-covered copper wire, tempered steel springs, and platinum contact points, are used in the medium grades. In the best qualities the finish is better.

A good bell has its working parts fixed to an iron frame, which is screwed to a seasoned teak or walnut back, and protected with a well-fitting cover of the same wood. The contact points are of platinum, and the wire of its coils is silk-covered. Bells of very common quality have stained deal backs and covers; the steel gongs and working parts are fixed to the wood backs separately without iron frames, the springs are of brass without silver, aluminium, or platinum contact points, the wire is cotton-covered, and the parts are often badly proportioned. In some bells an attempt at deceiving is made by soldering bits of German silver to the contact points, or merely putting a spot of solder alone on these parts. German silver and solder are both useless for contact points, as they soon corrode, and then the bell fails to ring. It is easy to test with a drop of nitric acid, which will turn green on German silver, and black on solder, but will not affect platinum. A drop of spirit of salts will dissolve aluminium; it will, however, have no effect on platinum, silver, or German silver.

In small houses, such as villa residences, a very cheap and pleasing system of electric bells may be established by employing a set of chime bells. These are sets of bell movements and gongs mounted on one base and protected with one cover. There are from three to eight gongs in a set, of different tones, each indicating the room from which the bell has been rung. Church-pattern bells, so called because they resemble in form the bells of a church belfry, are constructed so as to have the working mechanism inside the gong, which forms a *protective* cover. Owing to their ornamental

appearance, they may be fixed in any exposed position, as over doors, under archways, or mounted on brackets. The tone, although loud, is not dissonant or harsh, like that of ordinary bells. In addition to these varieties of electric bells, there are others adapted to special requirements, such as relay bells, employed on long outdoor lines; continuous action bells for burglar alarm systems, which continue ringing even when the lines are cut; bells with indicator movements in their cases; heavily mounted gongs in cases water- and weatherproof, for underground and outdoor use; electric buzzers, or movements without gongs, for sick-rooms and hospital wards; and electric trumpets, in which a vibrating diaphragm replaces the hammer and gong of the ordinary electric bell.

Electric bells are simple in construction, and as the various parts can be bought ready made, no great mechanical skill is required in making a bell. Electric bells vary very much in quality as well as in type. A continuous ringing electric bell of the right type may be bought from about 2s. upwards, according to quality and size, or one may be made by anyone accustomed to the use of tools who follows the directions printed in this chapter. A badly made bell with badly wound magnets and leaky connections will exhaust the battery. Hard or badly annealed iron used in the magnets will cause the armature to stick to them on the first contact, and fail to ring the bell. Badly fitted screws or badly constructed contacts, or the improper fixture of the metal parts to the wooden base, may cause the bell to fail to act when required.

The good and bad points of electric bells may here be noted as a guide to their choice. The wooden baseboard of a bell should be made of teak or mahogany, or some such wood not easily warped by changes in the moisture and temperature of the air. If the base is of metal, the contact pillar must be well insulated from the metal work with collars of ebonite above and below, and the connecting screws must be similarly insulated.

The set screw to the contact breaker should have good threads, be well fitted, and be provided with a good lock-nut. If this part is defective, the armature spring will work out of contact under the jarring action to which it is subjected. When the bell is caused to ring, try to stop it by placing the forefinger lightly on the armature; if this has a tendency to stick to the magnet, and does not readily re-start itself, the bell should be rejected, as doubtless the iron of the magnet has not been annealed. A

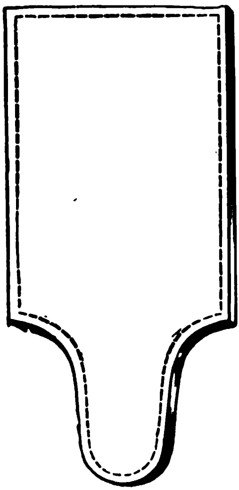


Fig. 87.—Wood Base-board of Electric Bell.

good electric bell magnet should attract iron filings when the current is passing through its coils, but should drop them the instant the current is interrupted. The contact set screw should have a tip of platinum in contact with a small plate of platinum soldered or riveted to the armature spring. These parts must be of platinum, but German silver or aluminium is sometimes substituted, as has been said. Nitric acid turns German silver green, and hydrochloric acid will dissolve

The following table shows the sizes of the magnet parts for bells of several different sizes :—

PROPORTIONATE SIZES OF MAGNETS.

Diameter of Bell.	*Length of Cores.*	*Diameter of Cores.*	*Length of Bobbin.*	*Diameter of Bobbin.*	*B. W. G. of Wire.*
In.	In.	In.	In.	In.	
$2\frac{1}{2}$	2	$\frac{5}{16}$	$1\frac{3}{4}$	$\frac{3}{4}$	24
3	$2\frac{1}{4}$	$\frac{3}{8}$	2	$\frac{7}{8}$	24
$3\frac{1}{2}$	$2\frac{1}{2}$	$\frac{7}{16}$	$2\frac{1}{4}$	1	22
4	$2\frac{3}{4}$	$\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{8}$	22
5	$3\frac{1}{4}$	$\frac{5}{8}$	3	$1\frac{3}{8}$	18
6	$3\frac{3}{4}$	$\frac{3}{4}$	$3\frac{1}{2}$	$1\frac{5}{8}$	16
7	$4\frac{1}{4}$	$\frac{7}{8}$	4	$1\frac{7}{8}$	16
8	$4\frac{3}{4}$	1	$4\frac{1}{2}$	$2\frac{1}{8}$	14
9	$5\frac{1}{4}$	$1\frac{1}{8}$	5	$2\frac{3}{8}$	14

The length given in the above table allows for the core ends being turned down and threaded to receive the

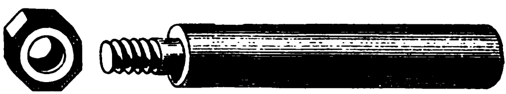


Fig. 92.—Magnet Core with Nut.

nuts (Fig. 92) which hold them in the yoke. Sometimes nuts are not used, but the cores are fixed to the yoke with screws entering the cores (Fig. 93). If this plan is adopted the ends of the cores must be drilled and tapped to receive the screws (Fig. 94), and it will not be necessary to cut the cores so long as when they are to be fastened by nuts. Fig. 95 shows even a simpler way; in this the core is riveted into the yoke. However good the iron may be, after the cores have been cut off it must be reannealed to make it quite soft. Cores made of hard iron, or imperfectly annealed, will retain some magnetic influence over the armature after contact is *broken* and the current has ceased. Iron is usually

annealed by heating to redness in a good fire, then covering fire and iron with hot ashes, and allowing all to cool gradually for some ten or twelve hours before

Fig. 93.—Section of Magnet Core.

disturbing the iron. After the cores are annealed, one end of each must be turned down to form a pin with shoulder to fit in the yoke, and the other ends filed level and smooth to form faces for the armature.

If the cores are to be riveted to the yoke as illustrated in Fig. 95, this riveting must next be done. If they are to be attached by nuts as in Fig. 92, the pins must

Fig. 94.—Magnet Core.

be screwed to fit the tapped nuts. If they are to be fastened by screws as in Fig. 93, the ends must be drilled and tapped. Yet another way of attaching the cores to the yoke is shown at Fig. 96. This arrangement for fixing the cores in the yoke should be done before the bobbins are wound with wire.

The yoke, as shown in Fig. 96, is the bar of metal to

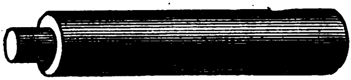


Fig. 95.—Magnet Core.

which the cores or legs of the magnet are attached. It should be made entirely of iron and the cores fixed to it, or its effect will be the same provided the two cores are connected by a strip of soft iron. A piece of angle iron of dimensions to suit the size of bobbin to be

A size suited for a 4-in. bell is 2 in. × $\frac{5}{8}$ in. × $\frac{3}{16}$ in. This piece of iron must be filed up flat and smooth; a hole is drilled in one end and tapped to take the screwed end of the hammer shaft; at the other end, in the positions shown, A, B, in Fig. 97, two holes are drilled and

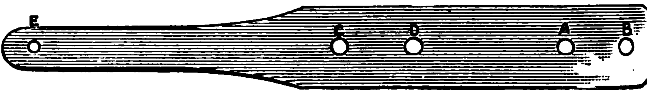


Fig. 98.—Armature Spring.

tapped to receive two small iron set screws intended to hold the armature spring shown in Fig. 98.

The armature spring may be made of spring brass, German silver, or steel. Its length and width are determined by the dimensions of the armature, but it must be long enough to extend from the lug S to the pillar at P,

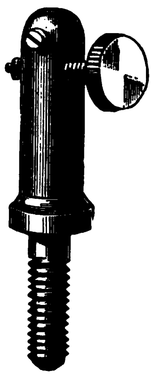


Fig. 99.—Contact or Break Pillar.

Figs. 88, 89, 90, and 91 (p. 102). It should be stiff enough to bring the armature back to the contact screw sharply after the bell has been struck, but not so stiff as to require a high battery power to work it. Two holes are drilled at A, B, Fig. 98, to receive screws to hold it to the

lug, S, Fig. 88, and two holes at C, D, to receive screws to attach it to the armature, Fig. 97. At E another small hole should be bored to receive a bit of No. 20 B.W.G. platinum wire, which, when riveted to the spring, forms the contact for the screw point.

The contact pillar and screw is shown with its accessories by Figs. 99, 100, 101, and 102. The pillar should be turned out of $\frac{1}{2}$-in. brass rod, the top part above the foot should be $\frac{3}{8}$ in. diameter, and the lower threaded part $\frac{1}{4}$ in. diameter, to receive the nut (Fig. 101), or to be screwed into the wood base; either method is adopted. Where the pillar is secured to the frame by a nut beneath the base, a recess is cut beneath the base for the nut, the connecting wire is carried through a small hole into this recess, and the end secured between the nut (Fig. 101)

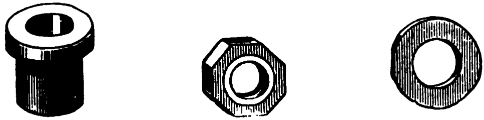


Fig. 100. Fig. 101. Fig. 102.

Fig. 100.—Insulating Collar. Fig. 101.—Brass Nut.
Fig. 102.—Brass Collar.

and the thin brass collar (Fig. 102). The threaded part of this pillar will pass through the hole, P, Fig. 88, in the metal frame, and must be insulated from the frame by a collar, which may be turned out of boxwood or ebonite to the shape shown in Fig. 100. The upper part of the pillar, Fig. 99, carries a brass contact screw to connect with the armature spring the current from the pillar. The screw is $\frac{1}{8}$ in. diameter, and $\frac{3}{4}$ in. long, and has a milled head, as shown. A small hole in the tip of this screw is plugged with a platinum wire which projects to form contact with the platinum at E on the armature spring. Platinum is used because the electric spark which passes at the point when the bell is ringing has very little effect on this metal, whilst it will destroy most other metals. A hole is drilled through the pillar, about $\frac{1}{4}$ in. from the

The bell itself is generally nickel-plated, and distinguished by the name of gong. The pillar to support the gong may be about $2\frac{1}{2}$ in. to 3 in. long, made of $\frac{3}{8}$ in. iron, turned and screwed at the ends, as shown at Fig. 105. The bottom part is screwed into the base and metal frame, or secured by a nut beneath the base. The

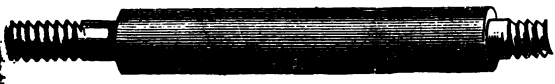


Fig. 105.—Bell Pillar.

top part passes through a hole in the centre of the gong, being secured by a brass milled head (Fig. 106).

Supposing, then, that all the necessary parts already mentioned in preceding pages have been got together, see that each part is proportionate; the metal frame to the base-board; the magnet coils and cores to the gong; the armature to the magnet; the spring suitable in length and stiffness; and the hammer-shaft sufficiently long to properly ring the bell.

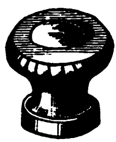


Fig. 106.—Milled Head for Bell Pillar.

Fig. 107.—Binding Screw.

The metal base plate, which should have countersunk holes for the heads of the screws used in fastening it to the wood base, may be fixed on first. Next fasten the yoke of the magnet to the base plate; then attach the cores to the yoke, and slip the wound bobbins on the cores. Strip off the silk covering from the inside ends of the two coils, clean the wires and twist them

together as previously explained, and serve the outside ends of the coils in a similar manner. Attach one of these to the left-hand terminal, or binding screw (Fig. 107) of the bell, and fix the other to the metal base plate or to the lug carrying the armature spring, in both cases using metal screws and making good connection between clean metals. This done, fasten the armature to its spring, and this to the lug on the base plate, and insert the hammer shaft in the ends of the armature.

The contact pillar (Fig. 99, p. 108) should now be fixed in its place, and in doing this, see that the insulating collar (Fig. 100, p. 109) entirely prevents the metal of the tang from touching the metal base plate. Next put in the gong pillar, and screw the gong in its proper place.

Now proceed to adjust the various parts of the movement. The armature spring must be bent so as to just touch the platinum tip of the screw on the contact post, when the hammer is about a quarter of an inch from the side of the gong; the armature spring should be just free from contact when the hammer touches the gong.

All connections may be made behind the base-board of the bell, to ensure safety from tampering, and for the sake of neatness. The wires are secured to the tangs of the various posts and terminals by brass nuts recessed in the base, and the wires led along in saw kerfs made in the back of the base. These recesses and kerfs should then be filled up with paraffin wax.

All parts having been connected, test the bell by trying to ring it with current from the battery. Adjust the contact screw of the break until the best tone is got out of the bell. If the armature taps the magnet cores as it vibrates, bend the spring a little outward so as to move it farther away from the cores. If it vibrates too freely, bring this part nearer the cores by bending the spring inward. It may be necessary to bend the hammer shaft to ensure it striking the gong properly. The battery power used in testing and adjusting the bell should be the same as that to be used in working it. A weak battery might just work the bell and a stronger

not ring it so well, whilst it might ring well with a strong battery, but fail altogether with a weaker one.

The working parts of an electric bell are very delicate, and liable to be injured by dust and damp, so they must be protected by a suitable cover. This is usually made from wood of the same kind as that employed in making the base-board of the bell. It is really a box without a cover, made out of ¼-in. wood, neatly put together with dovetailed joints or mitred corners strongly glued, and is highly polished when finished. Holes or notches are cut to allow free working of the hammer shaft and lever of relay. The cover is secured to the base by two brass hooks screwed to the sides, and engaging in brass staples fixed in the base. The top of this cover is attached to its sides by brass screws, in addition to glue, to give it greater strength. Two holes are drilled in the base close to the outside terminals; these are bushed with brass eyelets, and the bell is hung to a wall or a partition by means of screws passing through these, or by pins.

Those who wish to make a very simple and efficient bell can do so at a very little outlay by closely observing the following instructions.

The parts that ought to be bought are the gong, the silk-covered copper wire, two binding-screws, and a small piece of platinum wire (half the size and length of an ordinary pin will do) for the tips at the make-and-break arrangement. The binding-screws can be dispensed with by bringing out the working ends of the wire from the bell, and making a twisted joint to the line-wires; but this will not look so well. A few simple carpenter's tools, with a small drill and a soldering-bit, are all the tools needed. When nicely finished, and a nice little box made to cover the works, the bell looks very well.

It is supposed that the gong used will be 2½ in. in diameter. For the electro-magnet, which had better be the first part to begin with, get a piece of the softest round rod iron, not more than ¼ in. nor less than

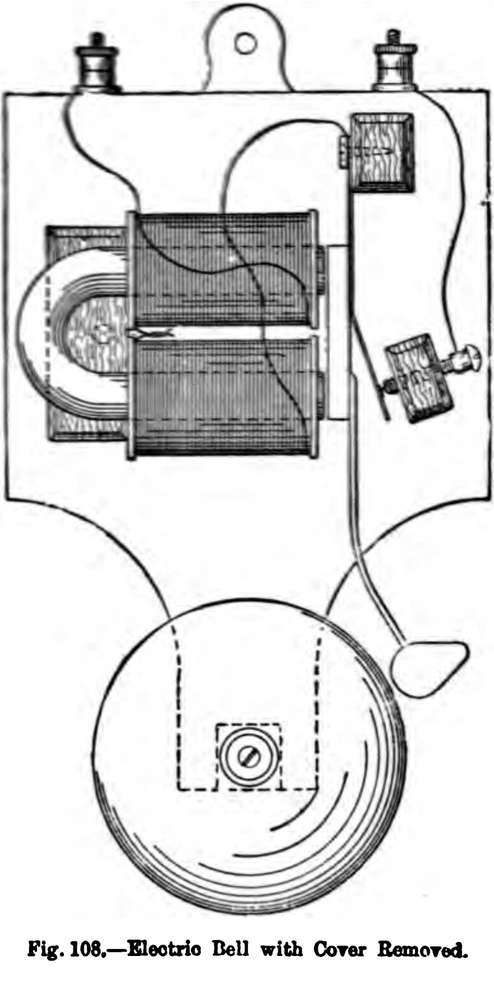


Fig. 108.—Electric Bell with Cover Removed.

$\frac{5}{16}$ in. in diameter. Bend the iron in the form of a horseshoe, Fig. 108, so that the arms are straight for $1\frac{3}{4}$ in. of their length, and are $\frac{5}{8}$ in. apart inside. Anneal the horseshoe so that it is sufficiently soft; to do this, make it red hot, and let it cool as gradually as possible, as explained on p. 105. Dress it up all over with a file, to

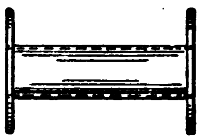


Fig. 109.

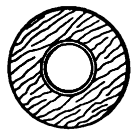


Fig. 110.

Figs. 109 and 110.—Front and Side Views of Bobbin.

take off the scale, etc., and file up the faces of the two ends true and square to one another, and quite smooth.

To make the bobbins shown in Figs. 109 and 110, to hold the coils of copper wire, take a round piece of wood the exact diameter of the magnet arms and about 4 in. long. Using this as a mould or mandrel, form the barrels of the two bobbins by twisting round two or three thick-

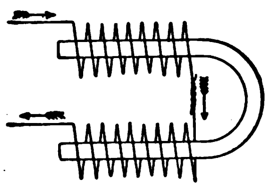


Fig. 111.—Diagram of Magnet Winding.

nesses of brown paper; fasten with thin glue, and slip them off the wood to dry; each should be $1\frac{1}{2}$ in. long. The ends of the bobbins are cut out of wood $\frac{1}{16}$ in. thick, and barely 1 in. in diameter; that will allow them to pass each other when slipping them on the arms of the magnet. They have holes through their centres to take the ends of the paper barrels (see Fig. 110), which are

fixed on with strong glue; the gluing should not be done until the barrels are quite dry. That part of the bobbins where the wire is to be coiled should have two thick coats of Brunswick black or sealing-wax varnish.

In making the coils of any horseshoe electro-magnet which requires a north pole at one end and a south at the other, the wire, regarded from the direction of the current that will pass through it, must be coiled in a reverse way on the two arms—that is, a right-hand twist on one arm and a left-hand on the other. A diagram is given in Fig. 111, and if the winding is followed in the direction of the arrows, this important matter of correct winding will be made clear. In practice the best rule is to wind both bobbins alike, beginning the same end of each, with the same twist for each; slip them both on the arms of the magnet in the same way, and then join together the beginning ends of the two coils, leaving the finishing ends to work from. Fig. 111 shows that, starting from the bottom and working to the top, each coil has really the same twist, and when the two beginnings are joined at the bottom as shown, the whole coil, taken as one length, has a right-hand twist on one arm and a left on the other, which will cause one pole of the horseshoe to become north and the other south when an electric current passes through the whole coil, thus creating the strongest form of magnet.

To wind the bobbins, procure a 4-oz. reel of No. 22 B.W.G. silk-covered copper wire; and if the bobbins have been made as directed, this will be more than enough, and will leave a bit to spare for odds and ends. The wooden mandrel used to mould the barrels of the bobbins on, fixed up as a little windlass with a handle, may be used; slip on one of the bobbins tight, and wind on six or seven layers until full of wire, winding tight and even as a new reel of cotton, and leaving 2 in. or 3 in. of spare wire at the beginnings, and 6 in. or 8 in. at the ends. Finish off by passing the end under the last loop of the coil and pulling tight. The insulation of the coils will be improved by a coat of Brunswick black,

and this will also help to hold all firm. Now slip the bobbins on the arms of the magnet, as directed above, letting the ends of the magnet arms protrude about $\frac{1}{32}$ in. Bare the beginning ends of the two coils, scrape quite bright, twist close together, and then solder the joint. The magnet and coils can be given a final coat of Brunswick black, all except the smooth bright ends of the magnet; these can be oiled to prevent rust. Twist up the two long unconnected ends of the coil on a penholder in the form of a helix, to be out of the way till they are wanted.

The base-board of the bell should be made as shown

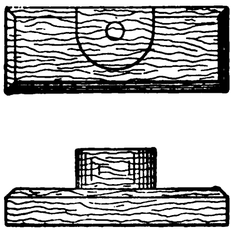


Fig. 112.—Plan and Elevation of Magnet Saddle.

in Fig. 108, of some $\frac{1}{2}$-in. stuff, such as mahogany, which always looks well; the exact shape does not much matter. Then a small wooden saddle must be made, as in Fig. 112. The small piece that stands up should fit behind the bobbin ends into the bend of the magnet, and the whole should be of such a height that the bobbins rest evenly on the base-board. Fix the saddle in its place, and glue it on tight. When dry, screw it to the board from behind with two small wood screws, drop the complete magnet into its place (Figs. 108 and 113); then, by a wooden button (Fig. 113), clamp all tight with a long wood screw, passing through to screw into the base-board.

The bell hammer, spring, and armature which plays in front of the ends of the magnet, may now be made.

a bit of platinum wire, and solder it into the hole in the screw; cut it off, leaving only a short piece of platinum projecting. Give it two or three taps with a light hammer to flatten it, and the platinum-tipped screw is made. Make from a scrap of sheet copper a small collar that will fit round the neck of the contact screw, loose enough to allow the screw to turn, and to this collar solder about 6 in. of the spare silk-covered copper wire; slip the platinum-tipped contact-screw through the collar, screw it through its wooden block, and glue the block to the base-board, so that the tip of the screw touches the small piece of platinum at the back of the spring.

In the connecting up, as the coils on the magnet have already been joined together only two free spirally twisted ends are left. Take one, bare the end, and clamp it under one of the binding-screws at the top of the base-board of the bell; then take the other end, bare it, and solder it to the brass cross-plate at the top of the hammer and armature spring; take the bit of covered wire that is fastened to the collar on the contact-screw, and clamp it under the other binding-screw. Remember, when making connections, always to bare and scrape the covered wire, so that metal may touch metal. Fig. 108 shows the connections.

Fixing the gong requires little explanation other than what is given by Figs. 108 and 116. The hammer shaft can be bent to get the head the proper distance from the gong. All the blocks, when the glue has set, should be screwed up with small wood screws from the back, but take care not to split them.

Platinum points are used so as to prevent corrosion, for where there is a rapid make-and-break of an electric current there is a great deal of sparking and burning, and platinum is almost the only thing that resists it. Any adjustment that may be required is done by the contact-screw. To finish the bell, make a neat little box (not forgetting the slits for the shaft of the hammer and the binding-screws) to cover up the works. Old *cigar-boxes* provide very good stuff for this purpose.

Varnish all the outside woodwork nicely, and a useful bell that has cost but a few pence will be complete.

The construction of a 2¼-in. electric bell will now be described. Parts for such a bell can be obtained, ready for putting together, base-board and cover included. Fig. 117 shows the malleable iron casting,

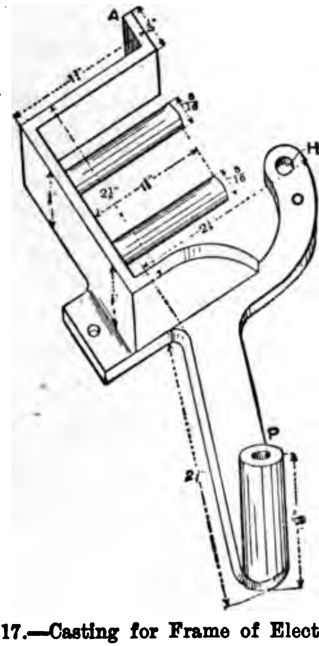


Fig. 117.—Casting for Frame of Electric Bell.

which serves the purpose of a support for all the working parts and also for the electro-magnet for the bell. A frame to this shape may be made of sheet iron if desired. The cores of the electro-magnet should be made of round soft iron, 1⅜ in. by $\frac{5}{16}$ in., and screwed into a lug on the frame.

Fig. 118 shows the armature, hammer, and contact-

the top of the pillar is then slit with a saw down to this hole, and a hole for another screw is drilled near the top of the pillar across this slit. When this screw is tightened the contact-screw is gripped and cannot shake loose. The contact-screw must be tipped with platinum in the way already explained. The stem of the contact-pillar must be insulated from the iron frame of the bell. This is done by bushing the hole, H, Fig. 117, with an insulating collar of ebonite, boxwood, or vulcanised fibre. A similar collar at the bottom insulates a brass nut which holds the pillar firmly to the frame.

A cover is held in position on the base, Fig. 123, by two brass hooks, Fig. 122, and this protects all the working parts from dust. Fig 123 shows all the parts mounted on a wood base 7½ in. in extreme length, 5 in. at the sides, 4 in. at the end, and ¾ in. in thickness. Two holes for holding screws are drilled through the corners and bushed with brass, and two terminal binding-screws are mounted between them. One wire goes from one of these terminals to the contact-pillar and the other wire goes to one end of the magnet coils.

As a conclusion to this chapter, the construction of an electric bell of the single-coil type will be described. Except that there is but one coil of wire, instead of two, and that the cast-iron ends of the core form the poles of the magnet, the bell shown by Fig. 124 is the same as an ordinary electric bell. The frame is one piece of cast iron, the core and ends of the magnet being in the centre, as shown in Fig. 125, which is a side elevation of the frame, and in Fig. 126, which is a plan of the frame. A projection is cast on at the top end, and to this is fixed the armature spring; on the projection at the lower end the gong is screwed.

The frame, gong, armature, hammer and spring, and the wire and case, may be purchased for a small sum. Two binding-screws or terminals will also be required.

The core and inner faces of the magnet edges should *be covered* with tape, so as to insulate them. The tape

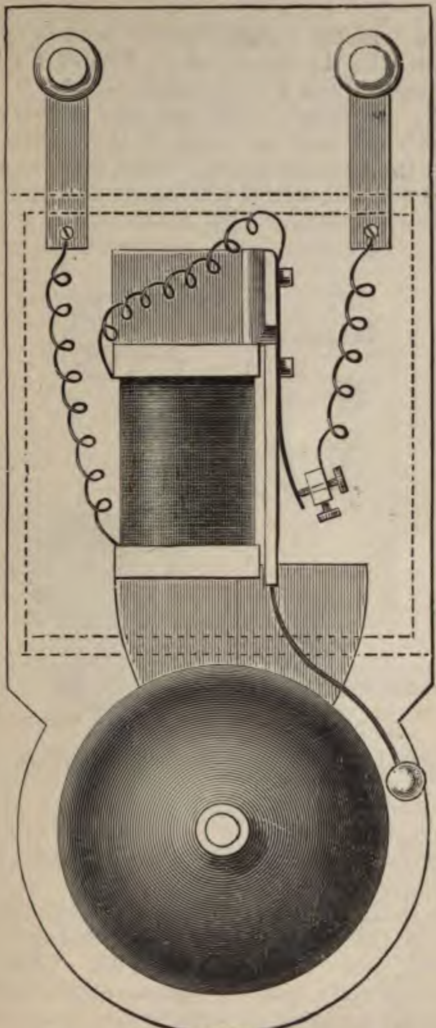


Fig. 124.—Single-coil Electric Bell.

is steeped in melted paraffin wax, and fixed by applying a hot iron to it. In the end of the bell-pillar a hole is drilled, tapped, and a screw fitted, to hold the bell; two holes are drilled in the frame for screwing it to the base-board, and two holes in the projection for carrying the armature spring. These must be tapped, and have two screws fitted into them. The positions of these holes are shown in Figs. 125 and 126.

The No. 28 silk-covered wire on the magnet core

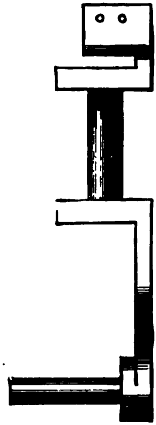


Fig. 125.

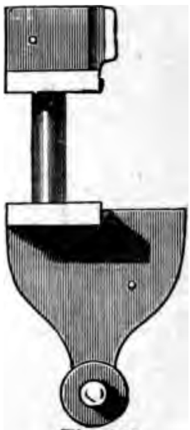


Fig. 126.

Figs. 125 and 126.—Frame of Single-coil Bell.

should be closely and evenly wound, and as many turns should be put on as will bring the wire to the level of the ends of the core, leaving about 3 in. at each end for connections.

The contact-spring must be fixed by two small screws to the armature, which is drilled and tapped to receive them. The spring is a piece of hard brass, having at its end a piece of platinum soldered on. The end is bent outwards to meet the contact screw, and two holes must be drilled in the spring to fix it

to the frame. The spring in position is shown by Fig. 124.

The hammer shank is screwed into the end of the armature, and bent, as shown in Fig. 124, in such a manner that when the armature is against the poles of the magnet the hammer head touches the bell. The bell is fixed on the pillar by a screw. A base-board of mahogany, ½ in. thick, is cut to shape, and to this the frame is screwed down.

The brass contact-pillar is L-shaped, $\frac{3}{16}$ in. thick and 1 in. long, with a milled-head brass screw at the level of the centre of the spring. The end of the screw must have a piece of platinum soldered to it, or a small hole may be drilled in the end of the screw and a piece of platinum wire soldered into it, leaving the end of the wire projecting. In the pillar, and at right angles to the brass screw, fix a small steel locking screw to keep the brass screw in position. The pillar is screwed to the base-board, but the screw must not touch the metal frame. At the top end of the base-board fix two binding-screws, and under them two strips of thin sheet brass, 1½ in. long, as shown in Fig. 124. The wires from the magnet must have the covering stripped off ½ in. at the ends, and scraped clean; each is formed into a ring, one being screwed down to one of the brass strips, and the other being attached to one of the screws in the end of the armature spring. Solder one end of a short length of wire to the contact-pillar, and fix the other end to the brass strip from the other binding-screw. To coil these wires, as shown, bind them on a piece of round stick. The spring should be made to touch the end of the screw when the armature is $\frac{1}{16}$ in. from the poles of the magnet.

As with the bells noted previously in this chapter, a wooden cover may be fixed with screws, or with two small hooks; the cover is indicated by dotted lines in Fig. 124.

CHAPTER VII.

PUSHES AND SWITCHES.

PUSHES used for closing electric-bell circuits may be of the very simplest construction; indeed, anything that will close the circuit in an electric-bell system will do for a push; pinching together the two bare ends of the line wire with finger and thumb will cause the bell to ring; so that really it does not require much ingenuity to construct something that will act as well as the usual form of push. On pp. 34 and 35 the principles of push construction are stated briefly, and examples of modern plain and decorated pushes are illustrated on pp. 36 and 37. It is the endeavour in this chapter to give instructions on making electric bell pushes of simple shapes.

Figs. 6 and 7, p. 34, show elevation and section of the wooden push whose construction is here to be explained.

The two wooden parts are the base and the cap, which must be neatly turned in a lathe. Fig. 7, p. 34, shows a section of the cap and base screwed together; Fig. 8, p. 35, is a plan of the base, which is slightly raised in the middle, with a screw thread cut on the raised edge to take the cap; Fig. 9, p. 35, shows a plan of the push as it appears when fixed to the wall

Having turned up the case in the lathe, two small springs must be cut out of thin spring brass, as in Fig. 127, and each fixed to the raised part of the base by means of two little screws (see Fig. 8, p. 35). The springs must be bent so that they do not touch each other either where screwed to the wooden base or at their free ends. These latter must be so placed that they are exactly over the centre of the push base, and under the hole in the middle of the wooden cap.

Fig 128 shows two views of the little push button, made of ivory, vulcanite, celluloid, etc., or of any hard wood. This button must be turned in the lathe, just of a size to fit quite easily in the hole in the middle of the cap. It is held in its place, when all is screwed up, by the little collar on its base, which rests on the upper swan-necked spring shown on the right in Fig. 127.

Two holes must be drilled through the base of the case, as shown by the two black spots in Fig. 8, p. 35; then from the back, pass through the two ends of the line wires from the bell and battery, bare the ends of each wire, scrape bright, and fasten one end under the screw of each spring (see Fig. 8, p. 35). One or two holes can also be drilled, anywhere out of the

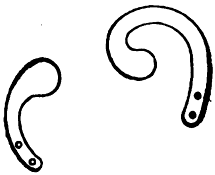


Fig. 127

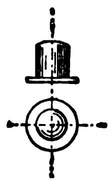


Fig. 128.

Fig. 127.—Springs of Bell Push ; Fig. 128.—Push Button

way, through the raised part of the base, in order to nail or screw the push in the desired position on the wall where it is to be fixed.

When the base is connected up and fixed, drop the button into the hole in the cap and screw the cap on to the base ; the button then should just touch the upper spring without pressing against it. It will now be seen that as soon as the button is pressed by the finger, the two springs will touch, and contact is made between the two line wires, the circuit thus being closed and the bell caused to ring. As soon as the finger is removed, the springs are parted, and the electric circuit is again broken.

Such is the construction of all circular bell-pushes,

which vary only in the material of which they are made. Pushes may be made without the help of a lathe, but then there must be some sacrifice in appearance. Figs. 129 and 130 show two views of a kind of key-push that may be constructed in the absence of a lathe; the two little plates of brass are joined to the two line-wires, and the little spring with the knob connects them when pressed down. This arrangement works just as well as the most expensive push, but of course does not look so neat.

How to make a secret electric bell-push for the front-door will now be explained; perhaps a front-

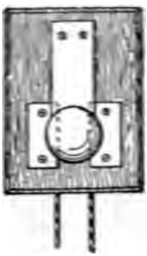


Fig. 129.

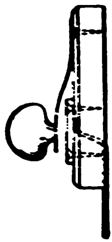


Fig. 130.

Figs. 129 and 130.—Simple Key-push.

door push that is unobtrusive is a more accurate definition. The push being very small, and fixed in an unlikely place for a bell-push, escapes notice, and—this, perhaps, being the main point—much annoyance from "run-away rings" is thereby avoided.

The idea is that the position of the push should be known only to those of the household. Of course, the push can be fixed anywhere thought proper. Ordinary front-door pushes are generally placed about 4 ft. 6 in. from the ground on the right-hand door jamb, and are often made conspicuous by the word "push" on the button. It is desirable to fix this secret push about *2 ft. 6 in.* from the ground on the left-hand door jamb,

just where it can be touched by a full-grown person without stooping or raising the hand, and where it is well within reach of a child. All that is visible from the outside is the end of a piece of iron or brass rod, ⅛ in. in diameter, and a small brass plate not much larger than a threepenny-piece (see Fig. 131); and if this little plate is made the centre of an imitation knot when the door is painted the push will be hardly distinguishable by those ignorant of its position.

The position of the push having been decided upon, the jamb of the door must be bored with a hole large enough to take quite easily a small iron or brass rod, in. in diameter. (See the section given by Fig. 132.)

Fig. 131.

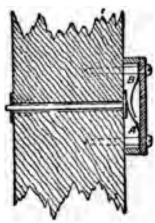


Fig. 132.

Figs. 131 and 132.—Front and Sectional Views of Secret Push.

Two views of this rod are shown by Fig. 133. For adjustment the rod should be made about ½ in. or so longer than is ultimately required; this will form what would be the button in an ordinary push. A brass plate, as small a one as possible, shaped as in Fig. 131, receives the outside end of the push-rod and is fixed to the door jamb. As before said, this little plate can be afterwards painted over to form the centre of a knot. Take care that the push works freely, or in wet weather there may be trouble. The little rod is assisted to run freely by clearing out the bored hole with a red-hot wire.

For the inside arrangement, and for the contacts, a small *shallow box* is made; Fig. 134 shows the back

Fig. 135 the inside, and Fig. 132 a section of this box. Two small brass springs, A and B, are bent into the shape shown in section in Fig. 132, and are fixed inside the little box by means of two small screws through each. They are made to overlap in the centre, but they must not touch each other. To one screw in each spring is fastened a short piece of covered copper wire, clamped tight under the screws, the ends, of course, bared of the insulating covering; these pieces of wire are brought out at the top of the box, and form the connections for the line wires to the bell and battery. (See Figs. 134 and 135.)

This little box, with the springs, etc., is fixed on

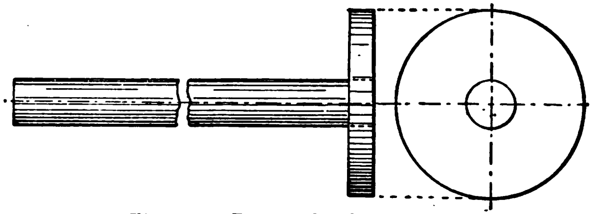


Fig. 133.—Button for Secret Push.

the inside of the door jamb in such a way that the button on the end of the small rod shall just press very gently against the upper or outer of the two springs without bringing them together. (See Fig. 132.) Having screwed up the little box in position, the connections can be made and the push tested with the bell and battery.

The amount of rod to be cut off may now be ascertained; the least possible amount may be left standing out to allow the push to work. This should be just enough to cause the two springs in the little box to touch each other when the rod end is pushed up close to the little outside plate. Having marked off the length, the little box must be taken off, the rod cut at the desired place, and the end nicely rounded off; finally, all can be re-fixed.

Switches are mentioned briefly on pp. 37 and 38, and illustrations of two-way switches are given on p. 39. It is intended to conclude this chapter by explaining how simple switches may be made.

Perhaps the simplest of all switches is that shown by Fig. 136. It is made from a small block of wood, three pieces of sheet brass, and a small spiral spring, and is connected up as shown, one piece of brass to one line and the other to the other line, with the brass lever to bridge across the two when pulled down. Its construction does not need further description.

Very often it is needful, in electric bell work, to cut off one bell from a push, or a number of pushes, and

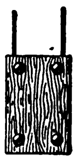


Fig. 134.

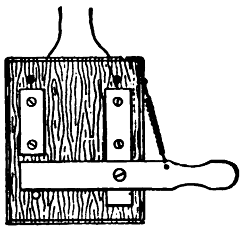


Fig. 136.

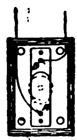


Fig. 135.

Figs. 134 and 135.—Connections for Secret Push; Fig. 136.—Simple Switch.

throw on another bell fixed in a different part of an establishment. In such a case a two-way switch may be employed, and this may be made at a very small outlay for material.

Having prepared a suitable piece of wood to form the base of the switch (shown in plan by Fig. 137, and in section by Fig. 138), set out the centre lines for the six small contact pieces, which must be cut out of some sheet brass about $\frac{1}{16}$ in. thick, each being drilled with two small holes for little brass wood screws, as shown in Fig. 139. It must be noticed that two of these pieces of brass are slightly longer than the others; these are to be placed just under the horizontal centre line, and are

to make continual contact with the two brass cheeks under the lever button. Before fixing these pieces of brass in their places, each must have a piece of ordinary bell wire, about 6 in. or 8 in. long, soldered underneath for connections. This soldering is done first by cleaning each piece of brass just between the screw holes, moistening with a little killed spirits of salts, and

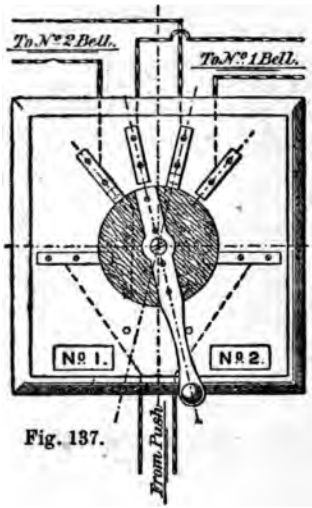


Fig. 137.

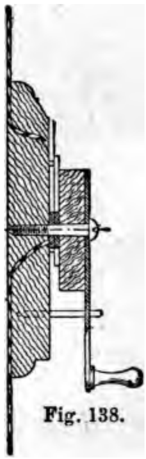


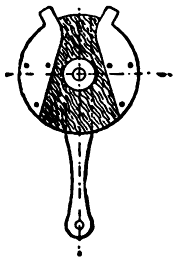
Fig. 138.

Figs. 137 and 138.—Plan and Sectional View of Two-way Switch.

running on a small touch of solder with the point of the soldering-bit; unwind the insulation for about ½ in. or so from the ends of the pieces of wire, and hold the cotton back by means of a couple of half-hitches; flatten out the bare tips of the copper wire by a few blows of a hammer, file clean, dip in killed spirits, and tin the tips with a small drop of solder from the soldering-bit; dip again in spirits, and solder them to the small pieces of brass.

On the centre lines on the base-board, where each little brass contact has to be placed, bore right through the wood and pass all the wire tags through to the back; see that the little contacts sit flat and true on the face of the wooden base; bring the wires from the four upper contacts to the top of the board, and the two wires from the horizontal contacts to the bottom (see Fig. 137). Sink all the wires by cutting grooves for them at the back of the board, and hold the wires in place with staples. Fig. 138 shows two wire tags passing behind and countersunk. The small

Fig. 139



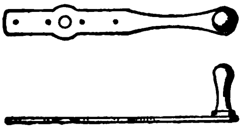


Fig. 141. Fig. 140.

Fig. 139.—Switch Contact-pieces; Fig. 140.—Lever and Button of Switch; Fig. 141.—Lever Handle.

brass contacts must be set out very carefully to shape and position shown in Fig. 137, which is drawn to scale.

Having screwed on all the pieces of brass with the little brass countersunk wood screws, all their faces must be worked down quite level. This may be done by holding the face of the base-board on a large flat board on which a sheet of emery paper has been laid, and working carefully with a slow circular motion. If every contact piece is not exactly level it will be impossible to make proper contact in the completed switch.

The turning, or movable, part of the switch—the front of which is shown in Fig. 137, a section in Fig. 138, and the back in Fig. 140—is a small wooden disc, on

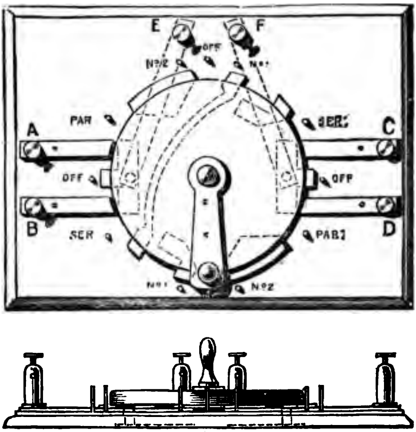
the back of which are fixed two brass cheeks, both alike, and cut from $\frac{1}{16}$-in. sheet brass (as in Fig. 140). Notice that these cheeks are fixed to the wooden button by three small brass screws each at their lower corners, so as to allow the upper parts, that have the small projecting lips, to spring just a little, in case of any unevenness in the small contact pieces on the base. After these brass cheeks have been screwed on to the wooden button, they must be worked down to a true and even face, and then the corners of the lips must be rounded slightly off with a file, the same being done to the four upper contact pieces on the base; this will allow the contact pieces to mount over one another when the switch is at work, and not jamb at the corners.

The centre of the wooden button should be drilled to take a good-sized brass coach-screw (see Fig. 138), and a neat little switch handle made as in Fig. 141, to be fixed on the front of the button. Two small brass washers will be required to go under the button, their combined thickness being exactly that of the brass contact pieces on the base and the brass cheeks on the button. They must be of large size for steadiness, but they must not touch either of the brass cheeks (see Fig. 140).

The whole switch can now be screwed up as in Figs. 137 and 138, so that the two horizontal contact pieces make continual contact with the brass cheeks on the button, and so that the lips on the brass cheeks can be placed so as to make contact with the first and third contact pieces (as in Fig. 137), or by shifting the lever handle so as to rest upon the second and fourth. The last thing to be done will be to shift the lever over to make good contact in one position, and put in a stop pin (see Figs. 137 and 138), then shift over for the other position and put in the other pin. The switch is now ready for varnishing or polishing. To connect up this switch, after having fixed its position, bring the wires from the *one bell to* the two tags, marked in Fig. 137 "To No. 2

bell," and the wires from the other bell to the other two tags on the top, marked "To No. 1 bell." The two tags at the bottom of the switch in Fig. 137 go to the push, or a system of pushes, and the battery. With the switch as shown in Fig. 137, the push and the battery are thrown on to the wires to No. 2 bell. The working can easily be seen by following the wires on Fig. 137.

Fig. 142 gives a general plan, and Fig. 143 an



Figs. 142 and 143.—Plan and Elevation of Universal Switch.

elevation of a small "universal" switch, particularly adapted for controlling or regulating the battery output on extensive electric bell and alarm systems.

The term "universal" may be said to be hardly correct in all cases; when only two cells are used it is quite correct, for each cell can be used by itself or the two can be used in series or in parallel. When, however, the box contains two batteries each of, say, three cells, each battery can be used alone; the whole six cells could be used in series, or the two batteries in parallel to one another, though this switch will not make

all the combinations. Nevertheless, it will be found a most useful switch, and, moreover, it is one that is very easily made.

Before setting to work to make the switch, it is advisable to make a full-sized working drawing of it. Cut out a disc of stiff paper to represent the revolving part of the switch, shown in Fig. 144, and pin this through the centre, in its proper place, on the drawing of the switch-board; then sketch in the small brass contact pieces and the contact strips, moving the paper disc at the same time, in order to see that all connections are made at the right positions.

The base of the switch-board should be true and

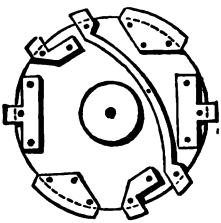


Fig. 144.—Under View of Switch Contact Maker.

flat and made of some hard wood, such as mahogany; this may be finished either by polishing or varnishing. At the back two grooves are cut, rather deeper towards the centre of the board than at the upper ends (see Figs. 145 and 146); these are to take the two contact strips, E and F, Fig. 142, the binding screws of which pass from the front through to the back, and are fastened to the strips behind. These strips, E and F, are furnished at the other ends with two brass pins, which pass to the front through two holes, which must be carefully set out. These pins should be very slightly rounded on the top, and stand up above the face of the board the same height as the thickness of the brass strips, A, B, C, D. These brass strips are fastened to the face of the board, and each has its binding screw; the board,

under these strips, should also be slightly cut away towards the inner ends, where the contact pieces on the revolving part of the switch move over them. If these instructions have been followed, and the little wood screws have been placed as shown in Figs. 142 and 145, it will be found that the strips, A, B, C, D, and the two pins on E and F, will all spring a little. This is most important, as it allows the little contact pieces to mount into position, and also ensures good contact.

Cut out all the little brass contact pieces (shown in

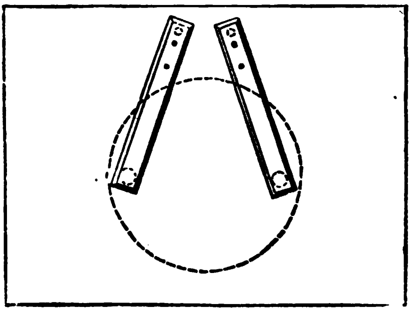


Fig. 145.—Under View of Switch-board.

Fig. 144), not forgetting to round off the edges of the tips, as where contact is made they mount on to the strips and pins. All the brass strips, contacts, washers, etc., should be cut from sheet brass of a uniform thickness, and all the small brass contacts should be screwed to the under face of a nicely turned piece of mahogany of a suitable thickness, great care being taken in setting them out. Countersink all the screws, and smooth the whole to a level face; drill a hole in the centre of the wooden disc, and bush it with a short piece of brass tube, of the size to take the neck of a stout brass coach-screw; make a neat handle, and fix in position on the top of the wooden disc, as in

Figs. 142 and 143. At the end of the arm of the handle a slight nick must be cut, to take the stop-pins at the different positions. The two brass washers one above the other (seen in the centre of Fig. 144), will raise the wooden disc the required height above the board, when all is screwed up. This screwing up completes the switch, with the exception of the stop-pins.

So as to explain more clearly how the connections are made, it is supposed that there are two cells only; and these cells will be called batteries No. 1 and No. 2. First place the switch handle in the position shown by

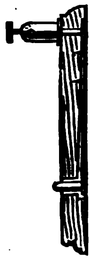


Fig. 146.—Sectional View of Switch-board Binding-screw.

Fig. 142, and drive in a stop-pin, made of spring brass wire, so that it rests in the nick at the end of the handle, and keeps it in position. The two T-shape contacts ought now to be between A B and C D, as in Fig. 142, breaking contact. Taking battery No. 1, connect the positive wire to the binding screw, A, and the negative one to the screw D; the positive wire of battery No. 2 goes to B, and the negative to C. By moving the switch handle a little way to the left—that is, to the stop-pin No. 1 in Fig. 142—it will be found that the T contact piece on the left connects the strip, A, and the pin and strip, E; the T contact piece on the right connects strip D, and the pin and strip, F—that is, No. 1 battery has been connected

up to the binding screws, E and F, which are the screws to connect the working lines. If the switch handle is moved to the right, the T pieces will make contact with B and C, connecting battery No. 2 with E and F. At all the points round the board stop-pins should be placed, and their exact positions must be fixed by actual experiment.

As a further example, move the handle to the series-pin, marked S E R, in Fig. 142, on the left. The long contact piece will now connect the strips A and C; the angular piece to the left will connect the strip, B, to the pin and strip, E; and the angular piece to the right will connect D to the pin and strip, F; the batteries will now be in series. Following the current from the work (the bell or system of bells as the case may be) it goes through the binding screw, strip and pin, F, to the angular piece on the right, then to the binding screw, D, and so through battery No. 1 to A, which is in direct communication with C; then through battery No. 2 to B, through the angular contact piece to the left, the pin and strip, E, and so back to the work.

The names of the stop-pins can be neatly written on small strips of drawing-paper and glued on the board before varnishing; or, bone tablets can be let in, and the whole polished; either way, the switch has a good appearance.

CHAPTER VIII.

INDICATORS FOR ELECTRIC BELL SYSTEMS.

INDICATORS are used on electric bell systems in which one bell is arranged to be rung from two or more points, and when it is necessary to know from which the signal has been sent. The essential working parts of an indicator are (1) an electro-magnet fixed to an iron frame; (2) an armature carrying a signal flag or vane of metal, which is moved when current passes through the coils of this electro-magnet to the bell. These parts are enclosed in an ornamental case furnished with little windows, through which the movements of the signal flags can be observed.

Indicator movements may be divided into three classes: (1) "mechanical replacement movements," which must be replaced by hand after the signals have been sent; (2) "electrical replacement movements," which may be replaced by sending an electric current back through their coils; (3) "pendulum indicator movements," which the electric current sets swinging like pendulums. In mechanical replacement indicator movements, the signalling vane is attached to a pivoted arm held in a position of rest by a tooth at one end of a lever attached to the armature. When current passes through the magnet coil, its core attracts the armature, pulling down that end of the lever, raising the opposite end, and thus disengaging the tooth from the signal arm. The vane then falls, and is seen at the window of the indicator case. It is replaced by means of a sliding rod at the side of the case, as shown in Fig. 147, which gives a general view of a mechanical replacement indicator.

In electrical replacement indicator movements the signal vane is mounted on the top of a balanced vertical arm. The lower part of this arm is fitted with a crescent-shaped permanent magnet, which half embraces the bobbin of the electro-magnet coil. With current passing through this coil in one direction, it attracts one pole of the electro-magnet and repels the other, thus throwing the vane to right or left, according to the direction of the current. When the direction of the current is reversed, the vane is thrown in the contrary direction. The movement can be thus replaced from a great

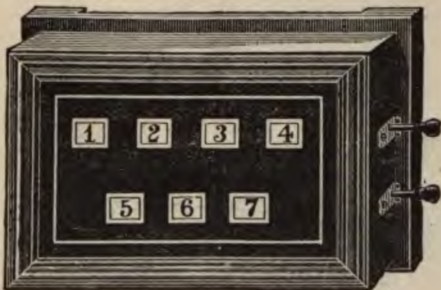


Fig. 147.—Mechanical Replacement Indicator.

distance, but is not so reliable as more simple instruments.

In pendulum indicator movements the signalling vane is fixed to the lower end of an arm, which is left free to vibrate or swing like a pendulum in front of the electro-magnet. This magnet attracts the iron arm when the current that rings the bell passes through the magnet coils, but releases it when the circuit is broken. The effect of this sets the arm, with its vane, swinging to and fro; if the movement is delicately poised, it will thus swing for a period of from sixty to eighty seconds. This is quite long enough for a person to observe its movements, and thus know from which room the signal is sent. As the arm is automatically replaced when it comes to

rest, no mistake can be made through omitting to push back a sliding bar or to press a button. The vanes or signal flags of indicators are usually made of thin sheet metal, such as zinc or tinned iron, enamelled in some bright colour, with a number written on it in black or white enamel or gold. These numbers correspond to those of the rooms from which the signals are sent. In some forms of indicators these numbers are dispensed with, and the names of the rooms written over the holes or windows in the indicator box. In other forms, the flags are metal frames to hold printed cards. When

Fig. 148.—Pendulum Indicator.

pendulum indicators are placed in dark or dimly-lighted passages, the vanes are made to hold slips of corrugated silvered glass, which reflect the light and enable those in movement to be easily seen. A general view of the latter kind of pendulum indicator is given by Fig. 148.

The pendulum is the simplest form of electric bell indicator and also the most reliable, for, as has been said, it requires no resetting when the bell has rung. In the 6-hole indicator about to be described the bell is fixed on the same board as the movement. An indicator having a greater or lesser number of movements or holes can be made without much trouble when once the principles of construction as here laid down are grasped.

The base-board, of mahogany or walnut, is about $\frac{5}{8}$ in. thick, 20 in. long, and about 10 in. wide; fix two strips of the same wood, 10 in. long and 2 in. wide, at the back of the board at right angles to the grain and near the ends to prevent the board warping and to leave a space of $\frac{3}{8}$ in. between a part of the board and the wall for the line wires. For each movement cut a piece of stout sheet iron to the shape shown in Fig. 149 and bend it at right angles across the dotted lines. This piece might be of sheet brass, but would then require a piece of sheet iron at the back of the cores to make the

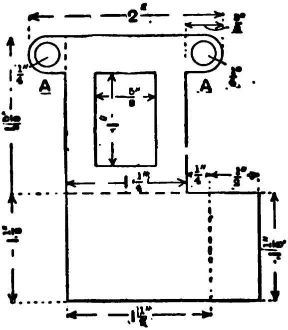


Fig. 149.

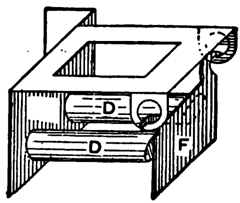


Fig. 150.

Fig. 149.—Pattern for Frame of Indicator Movement; Fig. 150.—Movement with Bobbins removed.

necessary magnetic connection. The two ears A, when bent down, form the supports from which the armature is suspended, as shown in Fig. 150. The armature F is cut to the shape shown in Fig. 151, and the hooks E are filed to a knife edge on the underside. The duration of the swing will depend to a great extent on the filing of these knife edges. To the outside of the armature is soldered a piece of brass wire J (Fig. 152) to carry the light paper vane H, which may be of any desired colour and design.

The two magnet cores D (Figs. 150 and 152) belonging

to each movement are of very soft round iron, $\frac{5}{16}$ in. diameter and $1\frac{1}{4}$ in. long, riveted or screwed to the iron framework; a good way to soften the cores is to put them in a red fire, then cover with ashes, and let the cores remain till the fire has died out. It will be noticed in Fig. 152 that each core is bevelled off at the end to allow more room for the armature to swing. The bobbins G (Fig. 152) are turned from boxwood, or can be made with brown-paper barrels and cardboard ends glued on; they are $\frac{5}{8}$ in. diameter and $1\frac{1}{8}$ in. long outside the ends, and are wound full with No. 24 or No. 26

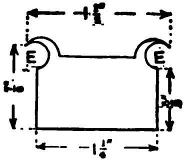


Fig. 151.

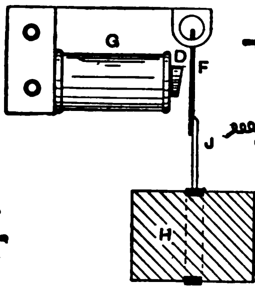


Fig. 152.

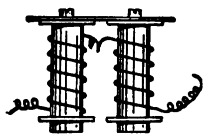


Fig. 153.

Fig. 151.—Armature for Indicator Movement; Fig. 152.—End Elevation of Movement; Fig. 153.—Diagram showing Magnet Winding.

S.W.G. silk-covered wire; the direction of winding is shown in Fig. 153. Wind both coils in the same direction, fix them in their places on the cores, and join the two commencing ends together, leaving the two finished ends to be used for connections.

When all the movements are made, proceed to mount them on the base-board, as shown in the diagram, Fig. 154; fix each with two small round-headed screws. On the base-board just above the movements are placed seven brass plates which form the terminals. They are $\frac{1}{2}$ in. long, $\frac{1}{4}$ in. wide, and about $\frac{1}{16}$ in. thick, and are

drilled for two brass screws. Round-headed wood screws are perhaps the best, as the wires can be clamped between the heads of the screws and the brass plates, but care must be taken not to cut the wires when forcing in the screws.

To give a neat appearance to the indicator, seven brass screwed terminals may be fixed outside and above the box which covers the movements, but brass

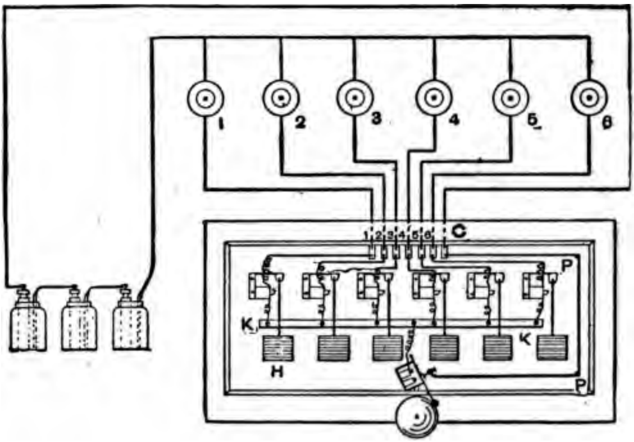
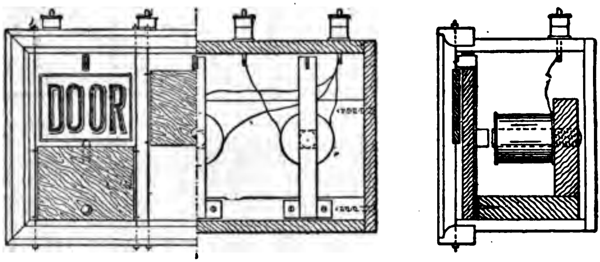


Fig. 154.—Diagram of Indicator Connections.

plates are easier to make, and cheaper. Fix the bell in the centre of the board, under the movements, but clear of the hanging vanes—Fig. 154. A strip of thin brass about $\frac{1}{4}$ in. wide (K, Fig. 154) reaches from the first to the last movement, and is screwed on the base-board. Wires are now taken from plates 1, 2, 3, 4, 5, and 6 (Fig. 154) to each corresponding movement, and the remaining wire from each movement is either soldered to the brass strip below or clamped under the round-headed brass wood screws which hold it. No. 22 s.w.g. silk-covered wire may be used for these inside

connections. Carried round brass pins, as P (Fig. 154), another wire must be taken from the remaining brass plate marked C (carbon) to the contact screw of the bell, the other connection of the bell being made to the brass strip. In soldering, use resin only as a flux, because if spirit of salts remained in the soldered joint it would soon eat away the wires.

Next make a box or case to cover the working parts. A hole is cut in the bottom of the cover for the hammer shaft to work through, the gong of the bell being left outside. This box cover has a glass front, which is painted inside with black enamel, a square or round



Figs. 155 and 156.—Half Elevation and Sections of Drop-shutter Indicator.

space of glass being left clear opposite each paper vane. Before blacking the glass, the name or number of the rooms may be written on the inside in white or gold paint above or under where these clear spaces will be; then when dry the glass may be blacked; thus there will be the coloured vanes only showing through the clear spaces in the glass.

Any fancy wood moulding can be used for the front of the case to hold the glass. Fix the indicator on a dry wall, and connect up the line wires from the various rooms, using wires of different colours so that each may be identified. Or, so that only two colours of wires need be used, run one wire to the zinc of the battery in one colour, say green, and then run

a green wire from each push and connect to the main green wire at the nearest point; then the other wires from each push may be run to the indicator in one other colour, say red. To determine the proper terminal with which to connect each wire, an assistant may close the circuit in room No. 1; each wire at the indicator is touched on terminal 1 until the wire is found that rings the bell. Of course, it is necessary that a wire from plate C has been connected to the carbon plate of the battery. Clamp the wire thus determined under the screw, send the assistant to room No. 2, touch each wire on No. 2 plate till the bell rings, and so on with all the pushes. The battery

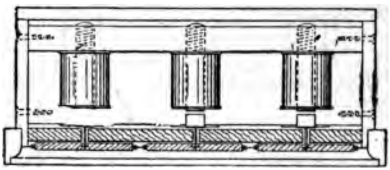


Fig. 157.—Horizontal Section through Indicator.

may consist of three No. 2 Leclanché cells, which should be connected in series.

The indicator it is proposed to discuss now is one having drop shutters which expose cards bearing suitable names, such as "Front Door" or "Ground Floor."

The indicator is shown in Fig. 155, half in elevation and half in sectional elevation. For making the case an old cigar box can be utilised; it should be cleaned up, and screwed together with little brass screws for extra strength; an old picture frame makes a suitable front for the case. This picture frame should be fitted and fixed to the bottom of the box, the lid making the back of the case, which should be hung on small brass hinges, so that access to the inside can be had at any time, should anything go wrong with the magnets or the springs.

Three electro-magnets will be required. Out of

some ½-in. deal cut two strips 2 in. wide, and of a length so as to fit inside the case or cigar box, with a little backward and forward play (see Fig. 156) for adjustment. Nail or screw them together in the form of the letter L, as shown in Fig. 156, where this part is shown in section, and in the upright part drill three ⅜-in. holes, properly spaced, and screw into them short bits of well-annealed ⅜-in. iron bolts, with their heads cut off and nicely faced up (see Figs. 156 and 157). These will form the cores of the three electro-magnets. Make three brown-paper bobbins, 1¼ in. long, with thin

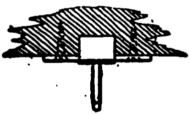


Fig. 158.

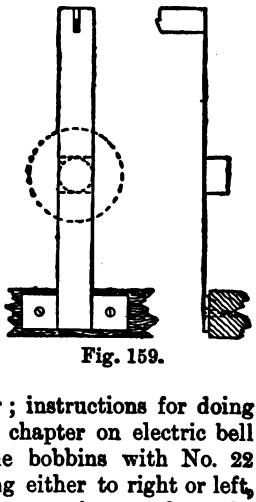


Fig. 159.

Figs. 158 and 159.—Plan and Elevations of Spring, Catch, etc., of Indicator.

wooden ends 1 in. in diameter; instructions for doing this are given on p. 115 in the chapter on electric bell construction. Fill each of the bobbins with No. 22 silk-covered copper wire winding either to right or left, but making sure that it is even; twist up the ends, which should be about 6 in. long, to be out of the way, and slip the bobbins on to the cores; fasten them by means of a drop of glue.

Figs. 158 and 159 show details of one catch, spring, armature, and little brass foot for fixing; of these there are three each. Pieces of clock mainspring about 3½ in. long. do very well for the springs. Straighten

the springs and at one end solder on pieces of sheet brass, drilled with two holes each (Figs. 158 and 159). Solder on the three soft iron armatures, $\frac{3}{8}$ in. square, $\frac{1}{4}$ in. thick; so that when the springs are fixed, the armatures will be opposite the magnets (see Fig. 156). At the top of the springs solder the brass catches, about $\frac{1}{2}$ in. long, and cut as shown to the right hand in Fig. 159. All these springs, etc., should now be screwed, by means of the brass feet, to the front of the L-shaped wooden frame that holds the magnets. If all is correct, the springs should stand up vertical, and each armature should be opposite to, and from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. away from, its

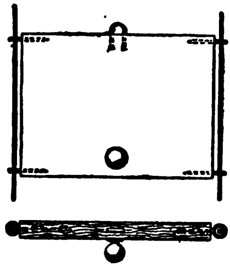


Fig. 160.—Drop-shutter for Indicator:

respective magnet. Slide the whole into the case, and mark the places where the holes are to be cut in the front of the case to allow the noses of the catches, at the tops of the springs, to go through without touching (see Figs. 155, 156, and 157).

The picture frame beading should now be cut, and put together to fit, and form the face of the instrument. Through the top and bottom are run six straight wires (see Figs. 155 and 156) to form the guides for the three shutters. Details are given in Fig. 160 of one of the shutters, which does not require further explanation. The shutters should be about half the height of the face, should run quite free, and should drop by their own weight. Fig. 155 shows one shutter

down and half of another one up; the little staples on the tops must be set out and fixed, to just hold on to the catches at the tops of the springs, which protrude through the face of the indicator.

Three small cards must be neatly printed—one "Door," a second "Ground Floor," and the third "First Floor;" these are to be of such a size when fixed to the face as to be quite hidden when the shutters are run up to their catches, but they are exposed fully to view when the shutters drop. Small stops should be fixed on the face to prevent the shutters being pushed up too far, and so injuring the catches and springs. These stop-pins are not shown on any of the illustrations, their positions depending on circumstances.

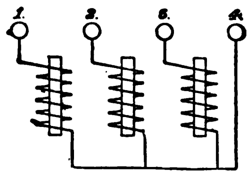


Fig. 161.—Internal Connections of Indicator.

Having fixed the frame, with the guides and shutters to form the face of the indicator, the magnets, etc., can be slipped from behind into place, and when they are pushed in so far that the noses of the catches just go far enough through to hold up the shutters, the magnet frame can be made fast by means of a few wood screws through the ends of the case (see dotted screws in Figs. 155 and 157).

On the top of the case put four binding screws, their shanks going well inside for connections. For convenience these binding screws will be numbered from left to right, 1, 2, 3, 4. Fig. 161 is a diagram of the connections inside the case. In an indicator of this kind it matters not which way the magnet bobbins are wound, but the connections must be as follows: One

end from each coil must be connected together, and all the three brought under binding screw 4, where they are fixed by a small touch of solder; the remaining ends of the three coils go to the binding screws, 1, 2, 3.

Much could be said, did space allow, of the methods of finishing the case of the indicator, the latter retaining a decidedly home-made appearance if not varnished or polished. Perhaps such work is hardly within the scope of the electric bell fitter, but it is necessary that something be said concerning it. Before either varnishing or polishing the indicator case it is desirable to remove any external brass- or other metal-work; this is improved in appearance by lacquering, a process also which prevents the metal tarnishing, a great consideration in damp situations. Do not, however, lacquer any terminals or other connections. Well clean up the case, first with medium and then with fine glasspaper, care being taken that all objectionable tool-marks are removed, as otherwise these will show up under the varnish. If the case is made of light wood it is a good plan to stain it darker, as then dust and dirt do not show up so much. Before staining, fill in the pores of the wood with a filling made by melting in an old iron spoon or ladle 3 parts of resin and 1 part of beeswax, a little dry brown umber being added to give the tone required ultimately. When the filling is hot, rub it into the work with a piece of wood, and when cold clean off with a chisel. If the case is already sufficiently dark in colour, leave out the brown umber. A coating of a weak solution of bichromate of potash will darken the wood. Wipe over with raw linseed oil when the stain is dry, smooth down with fine glasspaper, and finish off with two coats of good spirit varnish made by dissolving 4 oz. of shellac, 2 oz. of resin, and 2 oz. of gum benzoin in 1 pt. of methylated spirit. Strain this through muslin before using. The better class of indicators are given a rich polish, but polishing is a lengthy operation requiring much skill and experience. However, anyone wishing

to give the indicator case the very best possible appearance should consult "Wood Finishing," a companion handbook to this, which gives full instructions on polishing all sorts and sizes of work.

To test the instrument for working, connect a cell or battery by one of its poles to binding screw 4, and by means of a short piece of wire from the other pole of the battery, touch in succession the tops of the screws, 1, 2, 3, and the little shutters should drop one by one, exposing the printed cards. Should there be any hitch, slip the magnet frame out of the case, and

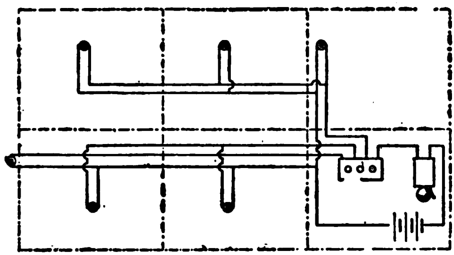


Fig. 162.—System with Indicator for Six-roomed House.

all can be made right by a little judicious bending of the springs, or the use of a small file on the catches.

The wiring of electric bell systems having indicators have already been described, but here may be given a few notes on a system for a six-roomed house in which the indicator just described may be employed with advantage.

Fig. 162 is a diagram of the wiring system. The bells, indicator, and battery had better be placed in the kitchen. Having fixed them, binding screw No. 4 on the indicator must be joined up to one binding screw on the bell, the other bell screw being joined to one pole of the battery. From the other pole of the battery the main line wire will run. Take this

right to the front-door push, with a return wire to No. 1 binding screw on the indicator. Then run branch wires from the battery main wire into the two rooms on the ground floor, and the return wires from these two pushes meeting, go back to No. 2 binding screw on the indicator. The first floor is run in the same way off the main to the three pushes, and the three return wires meeting, go back to No. 3 binding screw on the indicator. Branch wires and pushes are used in this case for the three top rooms and the two bottom ones, and a little attention to Fig. 162 should make this plain.

The working of the system is understood easily. On pressing the push in the middle room upstairs, the current runs from the battery through the push back to No. 3 binding screw on the indicator, round the coils of the magnet joined to No. 3 binding screw, which attracts its armature, and the catch allows the shutter to fall, exposing the words, "First Floor;" the current leaves that magnet to No. 4 binding screw on the indicator, then to the bell which rings, and so back to the battery. But a very little ingenuity need be employed to increase the system to suit any sized house.

Of course, the indicators in use in large hotels, etc., are far more elaborate than this instrument, but the principle upon which they work is the same. They have, for instance, springs, or small cords, to close all or any of the shutters, instead of a simple little brass knob as in the instrument described.

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